CALCULATOR - AIDED MICROWAVE NETWORK ANALYSIS

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THESIS

CALCULATOR - AIDED
MICROWAVE NETWORK ANALYSIS

by

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December 1974

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Calculator - Aided

Microwave Network Analysis

by

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Submitted in partial fulfillment of the
requirements for the degree of

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December 1974

ABSTRACT

The HP-8410S Microwave Network Analyzer System and the Wang 600 Programmable Calculating and Plotting System are discussed. An interface between the two is described and the feasibility of microwave network analysis under program control is demonstrated. Four calculator programs which implement S-parameter sampling and data reduction are described and documented.

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I. INTRODUCTION

The HP-8410S Microwave Network Analyzer System enables rapid characterization of microwave network components by determining complex scattering parameters, commonly referred to as S parameters. It provides a large amount of raw data by displaying these parameters in a continuous analog plot over octave bandwidths. Even though a large amount of data is provided, recording and interpretation must still be done manually. This is time consuming, and the accuracy provided by the network analyzer can be diminished by recording and reduction errors.

With this in mind, it was felt that the network analyzer system could be enhanced by the addition of a peripheral system to automatically sample the displayed S parameters at discrete frequencies, perform data reduction, plot and list the results. The purpose of this study was to demonstrate the feasibility of such a system by interfacing the Wang 600 Programmable Calculator System and the HP-8410S Microwave Network Analyzer System and developing several software programs.

II. S PARAMETERS

A. DESCRIPTION

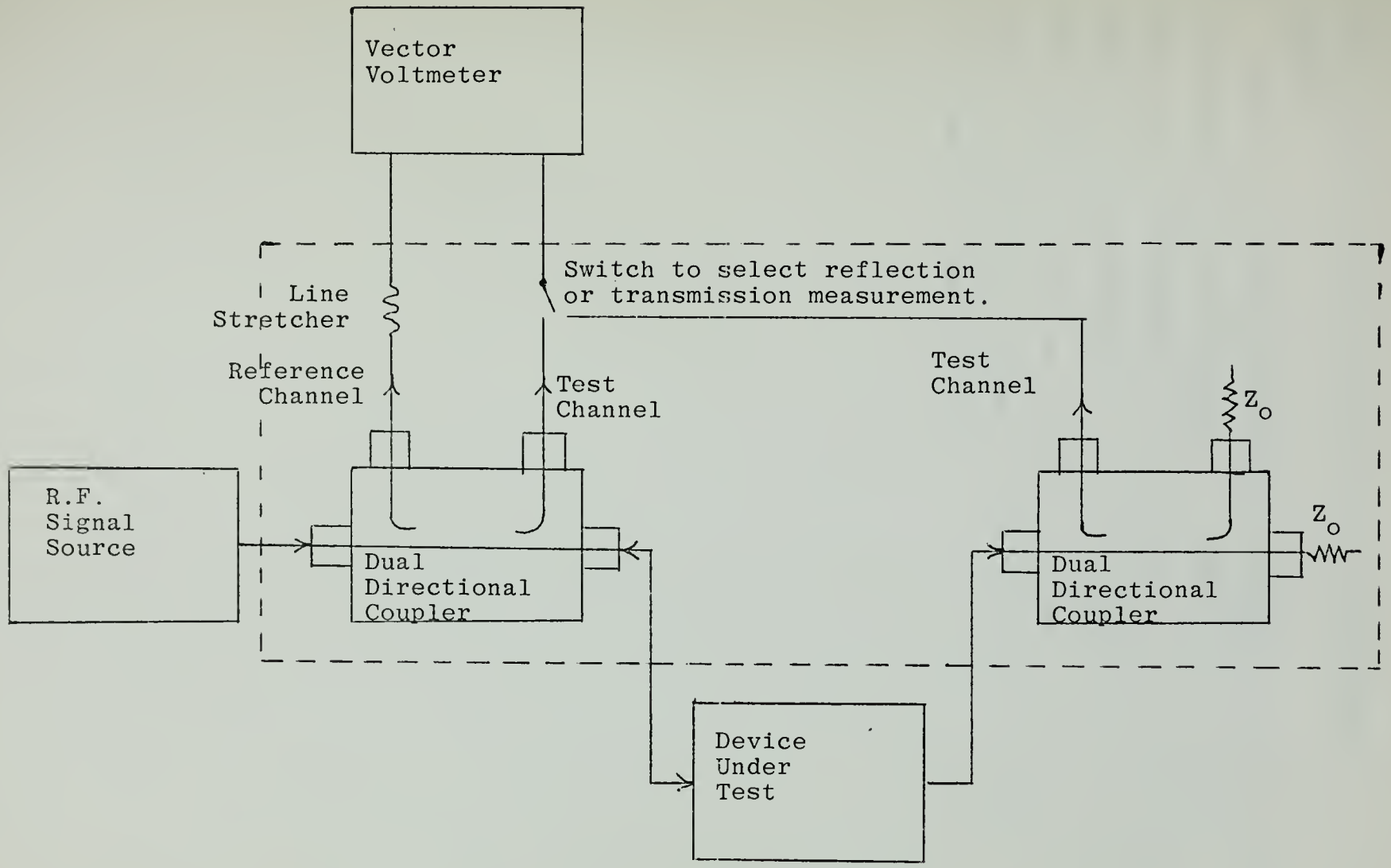
S parameters are obtained from reflection and transmission measurements of voltage waves incident on a test device. They are the ratios of complex signal voltages and contain both amplitude and phase information.

S parameters are preferred at microwave frequencies because they are measured with the device under test terminated in the characteristic impedance of the transmission line in which it is inserted. As a result, stray capacitance and lead inductance caused by open and short circuit terminations are eliminated. Also, semiconductor devices do not oscillate under test.

B. MEASUREMENT TECHNIQUE

A means of determining S parameters is by use of two dual directional couplers with the device to be tested inserted between and the system fed by a high frequency signal source. This technique is shown in block diagram form in Figure 1.

The ratio of the reference and test channel signals is obtained with a vector voltmeter. The characteristic impedance terminations on the second directional coupler prevent reflections. With this arrangement, S_{11} and S_{21} can be determined. To obtain S_{22} and S_{12}, the two



S - Parameter Measurement Technique

Figure 1

port device is turned around and the measurements repeated.

The part of the block diagram enclosed by dotted lines is referred to as a transducer. It splits the incoming signal into a reference and test channel, and provides the capability of extending the electrical length of the reference channel so that the reference and test signals travel the same electrical distance. This preserves the phase relationship between the two.

III. SYSTEM DESCRIPTION

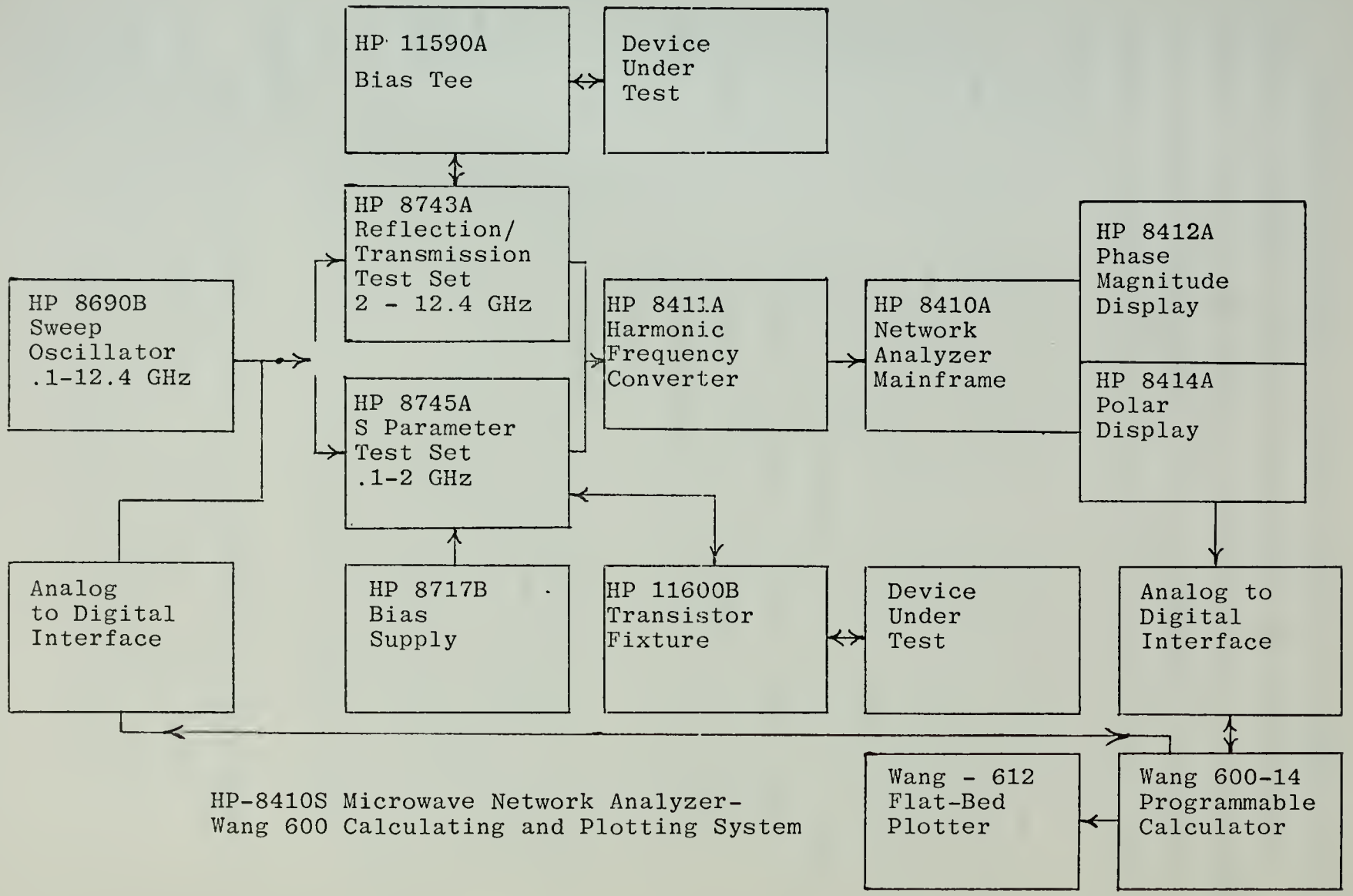
Figure 2 is a block diagram of the HP-8410S Microwave Network Analyzer - Wang 600 Calculating and Plotting System which is installed in the Naval Postgraduate School Microwave Laboratory.

A. MICROWAVE NETWORK ANALYZER

The HP-8690B Sweep Oscillator with the HP-8690B series RF plug-ins serves as the signal source for one of two transducers, either the HP-8743A Reflection-Transmission Test Unit or the HP-8745A S-Parameter Test Set, depending on the frequency range of operation desired.

These transducers are capable of both reflection and transmission measurements. They use dual directional couplers to split the incoming signal into reference and test channels. The device under test is connected to the front panel. Coaxial switches, operated by pushbuttons, connect the system correctly for the type measurement desired.

Available with the transducers are the HP-11600B Transistor Fixture, HP-8717B bias Supply and HP-11590A Bias Tee, which allow S parameter characterization of active semiconductor devices. Bipolar Transistors, FET's, diodes, negative resistance transferred electron devices, etc. can be easily and quickly analyzed for any specified bias condition.



HP-8410S Microwave Network Analyzer-
Wang 600 Calculating and Plotting System

Figure 2

The HP-8411A Harmonic Frequency Converter receives the test and reference channel signals from the transducer and converts them over a range of 0.11 to 12.4 GHz to a 20.278 MHz IF. Since the conversion is linear, the test and reference channel IF signals maintain their same relative amplitudes and phases.

Comparison of the two signals is accomplished by low frequency circuitry in the displays mounted in the HP-8410A Network Analyzer Mainframe. The mainframe provides phase-lock circuitry over an octave bandwidth to maintain the 20.278 MHz IF while frequency is being swept. It takes the ratio of the test and reference signals and then converts down to a second IF of 278 KHz. It has a precision 0 to 69 dB attenuator for accurate measurement of gain or attenuation of test channel amplitude.

The measured S parameters are displayed on the HP-8414A Polar Display or HP-8412A Phase-Magnitude Display. If the polar display is used, the parameters are read directly as magnitude and angle. If the phase-magnitude display is used, the parameters are in the form of return loss in dB, insertion loss or insertion gain in dB and phase in degrees versus frequency.

The polar display is most often used for measurement of reflection and transmission coefficients. The phase-magnitude display is effective for determining filter response such as skirt steepness and phase response linearity.

Smith Chart overlays are available with the polar display. These allow direct reading of normalized impedance in the case of reflection measurements since the Smith Chart is defined by $\frac{Z}{Z_o} = \frac{1 + \Gamma}{1 - \Gamma}$ where Γ is the reflection coefficient of the device under test and Z_o is the characteristic impedance of the transmission line in which the device is inserted.

B. CALCULATOR - PLOTTER

The Wang 600-14 Programmable Calculator has a programmable memory which allows program control of any operation which the calculator is capable of manually. It has a decision-making capability which allows branching and looping in programs. To write a program, the calculator is placed in the "Learn" mode and the sequence of operations desired is keyed. This results in the generation of four digit codes which are stored sequentially in memory. Each four digit code corresponds to a specific keyboard operation or a specific function selection and its corresponding register number. For example, the code 0815 means to take the number in the display register, invert it and put the result back in the display register. The code 0405 means to multiply the number in register five by the number in the display register and place the result back in register five.

To execute a program, the calculator is placed in the "Run" mode and the program is initiated by the operator. If the program has "Bugs," the calculator is again placed in the "Learn" mode and the program is stepped through. Each

program instruction is displayed as it is reached and is checked for correctness by the operator. When an incorrect code is found, the correct code is merely keyed in at the same location.

Programs can be recorded on magnetic tape for storage and future use. When a program which is on tape is needed, it is loaded directly into memory from the tape.

There are sixteen basic registers available for data storage. If only these sixteen are used, then programs up to 1,848 steps can be written. If the need arises for more than sixteen data storage registers, the calculator adapts by changing program step storage area into data storage registers. This is accomplished by taking eight program steps and grouping them together to form one register. If the entire memory is used for data storage registers, then there are 247 available.

The Wang Model 612 Flat-Bed Plotter provides line or point plotting and alphanumeric labeling. Format and content of the labeling is controlled by the calculator.

IV. ANALOG TO DIGITAL INTERFACE

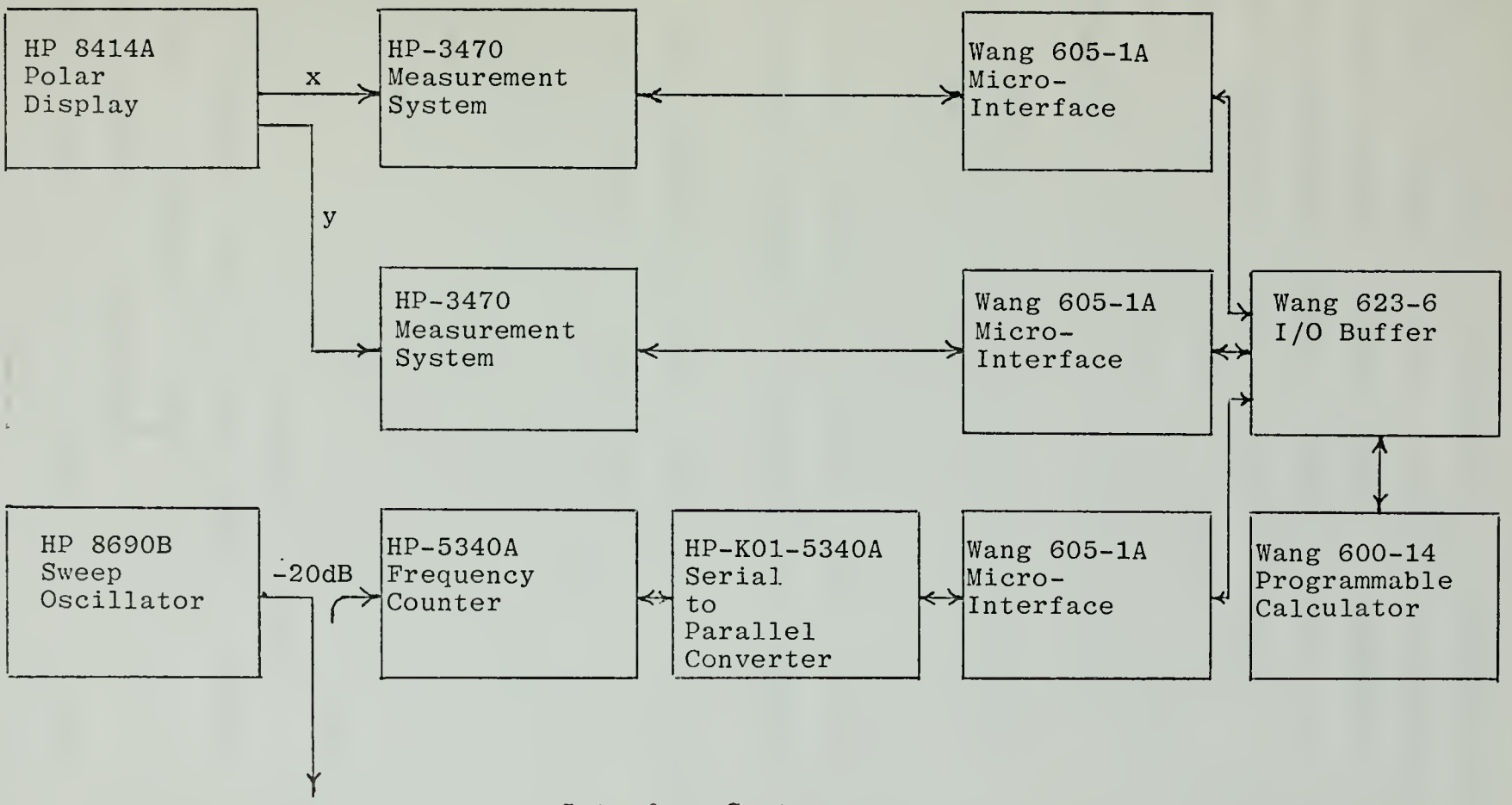
The analog to digital interfaces shown in Figure 2 were implemented by the author. A block diagram of the interface system is shown in Figure 3.

In the rear of the polar display, horizontal and vertical voltages directly proportional to the CRT deflection voltages are available. They are fed into two HP-3470 Measurement Systems where they are converted from analog to bit parallel character parallel 8421 BCD. After transfer to Wang 605-1A Micro Interfaces, these voltages are further converted to serial hexadecimal.

A portion of the output from the sweep oscillator is routed to a HP-5340A Frequency Counter by a -20dB directional coupler. After passing through the counter and a KO1-5340A Serial to Parallel Converter, the frequency enters a micro-interface as bit parallel character parallel 8421 BCD and is converted to serial hexadecimal.

Since three micro-interfaces are used, they are connected to a Wang 623-6 I/O Buffer to alleviate fan-out problems. The micro-interfaces transfer the voltages and frequency in serial hexadecimal form through the I/O buffer into the calculator's display register.

To implement the interface, it was necessary to compare connector diagrams of a micro-interface, a BCD module and the serial to parallel converter. These are shown in Figures



Interface System

Figure 3

4, 5, and 6. As a result of comparison, the connectors were wired as listed in Tables I and II. Logic level switches on the micro-interfaces were set as follows. For connection to BCD module; sign, down; print, up; execute, down; logic level, down. For connection to serial to parallel converter; sign, doesn't matter; print, up; execute, up; logic level, down.

A description of each interface component and control signal interaction is given in the following section.

A. INTERFACE COMPONENT AND CONTROL SIGNAL DESCRIPTION

The Wang 605-1A Micro-Interface is an input-only interface which accepts up to seven digits plus sign of bit parallel character parallel 8421 BCD and converts it into serial hexadecimal for input to the calculator's display register.

Input logic levels are TTL/DTL compatible with nominal values of zero volts for "O" state and +5 volts for "1" state. One output and one input control signal are provided and are respectively "Execute" and "Print." "Execute" is a switch selectable d.c. condition of zero volts or +5 volts, and indicates that the micro-interface is ready to receive data. "Print" is an input strobe of 5 microsecond minimum duration which can be positive or negative. A switch allows the micro-interface to adapt to either polarity. "Print" indicates that the peripheral to which the micro-interface is attached is about to transfer data.

Two 36 wire cables are used for data input and output. The output cable is factory wired to a 36 pin male Amphenol

Micro-Interface Connector Diagram

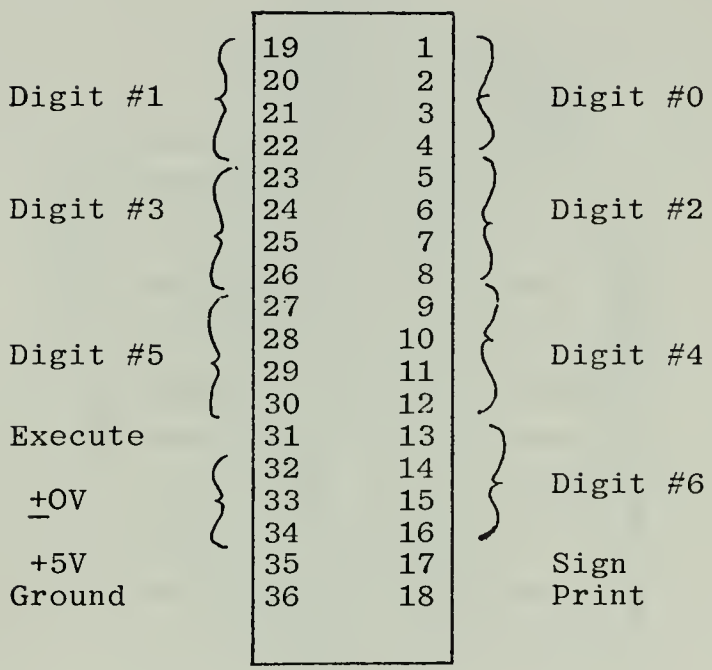


Figure 4

BCD Module Connector Diagram

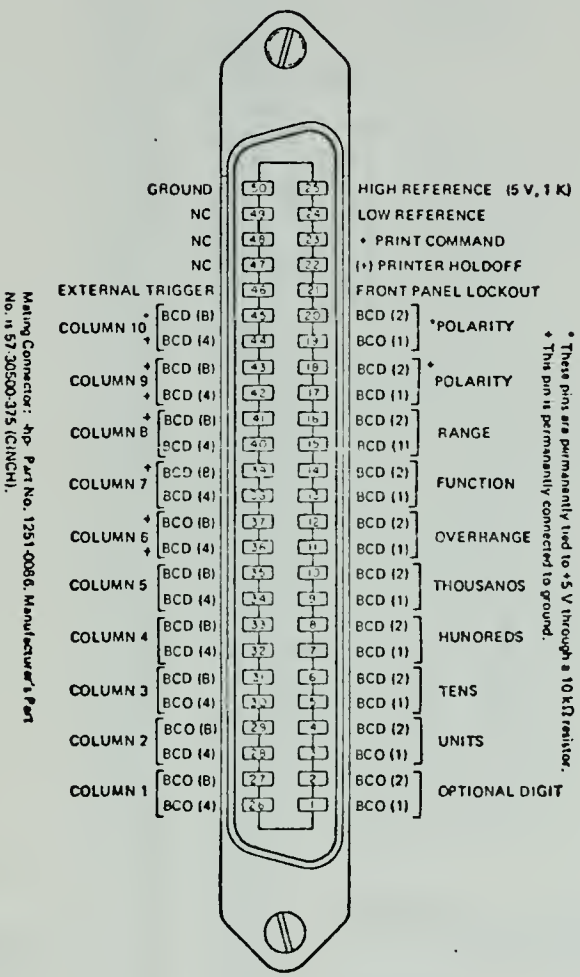


Figure 5

Serial to Parallel Converter Connector Diagram

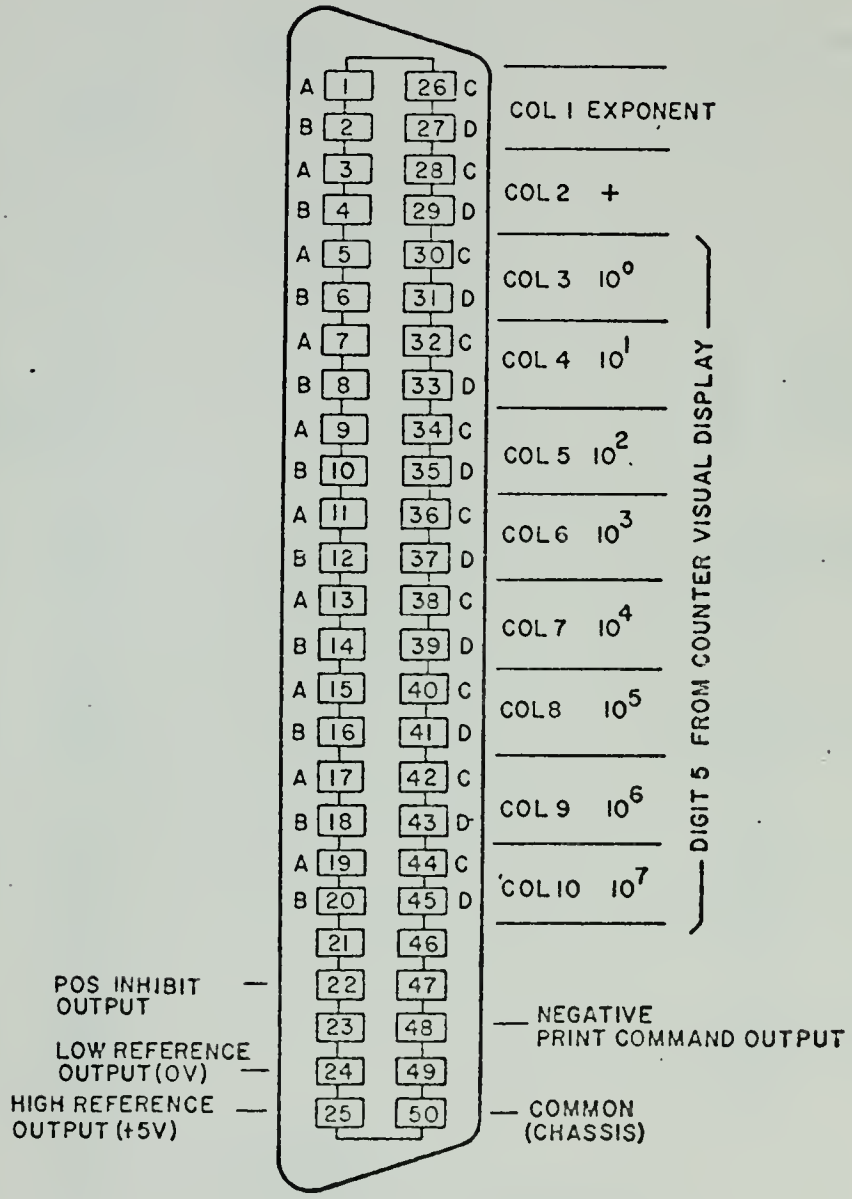


Figure 6

MICRO-INTERFACE-BCD MODULE WIRING LIST

Micro-Interface Wire Numbers			BCD Module Connector Pin Numbers	
Digit #0	1, 2, 3, 4, 5, 7, 32, 33, 34	bundle	24 ±0 Volts	
	6	unconnected		
	8	"		
Ground	36	"		
Sign	17		19	Polarity
Print	18		23	Print
Execute	31		46	External Trigger
+5 Volts	35		25	+5 Volts
Digit #6	13, 14, 15, 16		1, 2, 26, 27	Optional Digit
Digit #5	27, 28, 29, 30		3, 4, 28, 29	Units
Digit #4	9, 10, 11, 12		5, 6, 30, 31	Tens
Digit #3	23, 24, 25, 26		7, 8, 32, 33	Hundreds
Digit #2	5 6 7 8	to bundle unconnected to bundle unconnected	Generates Decimal Point	
Digit #1	19, 20, 21, 22		9, 10, 34, 35	Thousands

TABLE I

MICRO-INTERFACE-SERIAL TO PARALLEL CONVERTER WIRING LIST

Micro-Interface Wire Numbers			Serial to Parallel Converter Connector Pin Numbers	
±0 Volts	32, 33, 34	bundle	24	±0 Volts
Sign	17	unconnected		
Ground	36	"		
Print	18		48	Print
Execute	31		22	Inhibit
+5 Volts	35		25	+5 Volts
Digit #6	13, 14, 15, 16		1, 2, 26, 27	Exponent
Digit #5	27, 28, 29, 30		9, 10, 34, 35	10^2
Digit #4	9, 10, 11, 12		11, 12, 36, 37	10^3
Digit #3	23, 24, 25, 26		13, 14, 38, 39	10^4
Digit #2	5, 6, 7, 8		15, 16, 40, 41	10^5
Digit #1	19, 20, 21, 22		17, 18, 42, 43	10^6
Digit #0	1, 2, 3, 4		19, 20, 44, 45	10^7

TABLE II

connector and plugs into the I/O buffer. The input cable has one end factory wired to a 36 pin male Amphenol connector which plugs into the micro-interface. The other end consists of 36 exposed, numbered wires which can be wired to a suitable connector for attachment to a peripheral.

The HP-3470 Measurement System consists of a HP-34701A DC Voltmeter, a HP-34740A Display and a HP-34721 BCD Module. The d.c. voltmeter reads an analog voltage, the display converts it into character serial digital form and displays it. The BCD module converts the character serial data from the display into bit parallel character parallel 8421 BCD for input to a HP-5055A Digital Recorder or equivalent. In this case, the input is to a micro-interface rather than a digital recorder. BCD module output is through a 50 pin rear panel connector. Ten columns are available, five are for the digits in the Display, one for overrange, one for function, one for range and two for polarity.

The d.c. voltmeter has four voltage ranges of operation, 0 to $\pm$1, 0 to $\pm$10, 0 to $\pm$100, and 0 to $\pm$1000. The display has four digits plus and overrange digit which completes the readout on measurements above full scale up to 100% overrange. When 100% overrange is reached, all digits except the overrange digit are blanked.

The maximum useable x or y output from the polar display is $\pm$2.1 volts. Therefore, the 0 to $\pm$1 volt range on the d.c. voltmeter cannot be used because even with the overrange digit feature on the display, the maximum voltage which can

be displayed is 1.9999 volts. Any larger voltage yields 1.____. Thus, the 0 to ±10 volt range is used. This range gives a digital output adequate to cover the x and y voltage range with three decimal point accuracy.

The logic level of the BCD module is the same as that of the micro-interface. It allows for three input control signals, "Front Panel Lockout," "(+) Printer Hold-off," and "External Trigger," and provides one output control signal, "Print." The input control signal of consequence here is "External Trigger," which is a +5 volt d.c. pulse of one microsecond minimum duration.

With the front panel output rate switch in the hold position, the display will be sampled by the BCD module only when the "External Trigger" pin is at +5 volts or the "Manual" pushbutton is pressed. When the micro-interface sends its "Execute" command to the external trigger pin on the BCD module connector, it responds by sequentially transferring the data in the display into output data registers. During this transfer, conversion from bit parallel character serial 8421 BCD to bit parallel character parallel 8421 BCD occurs.

The BCD module next sends its "Print" command, followed by the parallel transfer of the number in its output data registers to the micro-interface. Once there, this number is converted to serial hexadecimal and transferred into the display register of the calculator. When transfer is complete, the "Execute" command from the micro-interface is returned to its original d.c. state of 0 volts and control is returned to the calculator.

The HP-5340A Frequency Counter provides a digital display of measured frequency and outputs bit parallel character serial "1" state negative ASCII to a 24 pin rear panel connector. A HP-K01-5340A Serial to Parallel Converter is used to convert this into bit parallel, character parallel 8421 BCD for input to a HP-5050A/B or HP-5055A Digital Recorder with the counter functioning as "Talker" and the recorder as "Listener." In this case, the input is to a micro-interface rather than a digital recorder.

The serial to parallel converter has as input from the frequency counter a 24 wire cable and as output a 50 pin connector which outputs ten columns of bit parallel character parallel 8421 BCD. Eight columns are for the digits displayed in the window of the frequency counter, and two columns are for a positive single digit exponent. The exponent is used to designate decimal point location with hertz as the measurement unit. Blanked zeros in the frequency counter's display are output as zeros by the serial to parallel converter. The 50 pin connector provides one input command, "Inhibit," and one output command, "Print." Logic levels are the same as those of the micro-interface.

Unlike the BCD module, which can have its sample and output rate controlled by "External Trigger," the converter was designed to enable the frequency counter to operate in the "Talk Always" mode to a digital recorder. This means that no "External Trigger" input is available to control sample and output rate. The frequency counter samples its

display window and issues a "Print" command at the rate determined by its internal rate generator. However, the converter provides a means by which the frequency counter will not output data until a record cycle is complete. When the frequency counter samples a frequency and generates a BCD output, the converter issues a "Print" command to the digital recorder. The recorder responds with an "Inhibit" command which causes the converter to prevent any further frequency sampling by the counter. The recorder removes the "Inhibit" command when recording is complete. The converter then allows another count-record cycle to be started.

In order to control sample and output rate of the frequency counter, the "Execute" command line from the micro-interface is connected to the "Inhibit" pin on the converter and has its logic level set so that when the micro-interface is not requesting data from the frequency counter, +5 volts are applied to the "Inhibit" pin of the converter. When the micro-interface sends its "Execute" command to the converter, the +5 volts are removed. This causes the converter to allow the frequency counter to function and send data to the converter which issues a "Print" command and transfers the data to the micro-interface. After the data is transferred to the calculator's display register, the "Execute" command is removed and +5 volts are again applied to the "Inhibit" pin of the converter, thus preventing any further sampling by the counter.

B. DIGIT WIRING

Any one of the seven input digits to the micro-interface can be wired to generate a decimal. Since four significant digits are transferred from the BCD module to the micro-interface, and since the voltages measured are always within the 10 volt range of the d.c. voltmeter, the micro-interface is wired to generate a decimal which follows the most significant digit of the input voltage. This was accomplished by wiring digit #2 on the micro-interface as a decimal. The least significant digit of the input voltage is wired to digit #5, the most significant to digit #1. The other digits are wired in order between. Digit #0 is unused and digit #6 is wired to the optional digit input from the BCD module.

If the HP-34750A Display were used instead of the HP-34740A Display, the optional digit would give another decimal point of accuracy. Since the HP-34740A Display is used, the optional digit always appears as a zero when transferred to the calculator's display register.

Eight digits, a plus sign and an exponent are output by the serial to parallel converter. The micro-interface can only accept seven digits. Therefore, only the six most significant digits of the frequency measurement and the exponent are wired to the micro-interface connector. The plus sign which preceeds the exponent is unnecessary. The exponent digit is wired to digit #6 on the micro-interface and the most significant digit of the frequency is wired to digit #0. The other digits are wired in order between.

Since two digits of the frequency are not sent to the micro-interface, the exponent is in error and must have two added to it to give a correct reading when displayed in the calculator's display register. This is accomplished with a short calculator subroutine.

V. CALCULATOR PROGRAMMING

Four programs to demonstrate the feasibility of calculator-aided microwave network analysis were written by the author. In general terms they can be described as follows.

The x and y voltages from the polar display and the frequency of the sweep oscillator's output are called for sequentially by the calculator. Each micro-interface has a switch selectable address which can be any number from 00 through 15. When a calculator program requires raw data, the calculator transfers control to a micro-interface, which then interrogates the peripheral to which it is attached. The peripheral responds with the data to the micro-interface, which transfers it to the calculator's display register. Once in the display register, it is moved to a storage location.

When this cycle is complete, program control returns to the calculator and another micro-interface is given control, or if the data sampling desired by the program is finished, then data reduction proceeds in the calculator.

The reduced data is stored by the calculator and then plotted by the plotter under program control in the form desired. The data can also be listed beside the plot or printed out on the calculator's 21-column drum printer.

A. S_{11}/S_{22} - PRINTING

This program uses the calculator's 21-column drum printer to type out ten items derived from reflection measurements using the polar display. These are frequency, VSWR, Re Γ, Im Γ, $|\Gamma|$, $\angle\Gamma$, Re z, Im z, $|z|$, and $\angle z$. The Program is designed to be executed on a point by point basis i.e. a point is taken and the reduced data typed out before another point is taken.

Figure 7 shows a typical output.

B. SMITH CHART - PLOTTING AND LISTING

This program uses the plotter as the output device and is designed for reflection measurements on the polar display. A maximum of 41 data points can be taken. Forty-two or more will cause data to be stored in memory locations which contain program steps and will result in program errors. A simplified Smith Chart is drawn and the points plotted on it. Frequency and real and imaginary parts of normalized impedance of each point are listed beside the chart.

The program can be used for devices which exhibit a negative real part of impedance ($\Gamma > 1$), such as transferred electron devices, as well as devices which have a positive real part of impedance ($\Gamma \leq 1$). This flexibility results from a routine which tests each point before it is plotted to determine if $\Gamma > 1$ or if $\Gamma \leq 1$. If $\Gamma > 1$, the location of the point to be plotted on the Smith Chart is obtained from the inverse of the complex conjugate of the measured

Reflection measurement of input to a JAN2N3866 Transistor at .5004 GHz. Bias Conditions; V_{CE} = 5 Volts, I_E = 50 ma.

	5,004 x 10^5 Hz	
Frequency	50045.0000	D
VSWR	3.5573	D
Re Γ	-.3866	D
Im Γ	.4066	D
$\lvert\Gamma\rvert$	.5611	D
$\angle\Gamma$	133.5558	D
Re z	.3280	D
Im z	.3894	D
$\lvert z\rvert$	.5092	D
$\angle z$	-310.1091	D

Figure 7

reflection coefficient. The Smith Chart lines of constant resistance are then interpreted as negative and the impedance print out has its real part negative. If $\Gamma \leq 1$, the location of the point is obtained from the unchanged measured reflection coefficient, the lines of constant resistance are interpreted as positive and the impedance print out has its real part positive.

To measure $\Gamma > 1$, the display must be compressed to place the point on the CRT. This is accomplished by attenuating the test channel signal. The difference between the dB setting necessary to calibrate the network analyzer and the attenuation in dB's applied to the test channel is entered into the program by the operator via the keyboard. The program uses this value to plot the points correctly on the Smith Chart.

Figures 8 and 9 show typical outputs.

C. S_{12}/S_{21} POLAR COORDINATES - PLOTTING AND LISTING

This program is designed for transmission measurements using the polar display. A maximum of 36 data points can be taken. Thirty-seven or more will result in program errors. A polar coordinate system is drawn and the value of the outer circle radius is printed. Frequency and magnitude and angle of each transmission coefficient are listed beside the plot.

The program can be used for transmission coefficients either larger or smaller than one. To measure a transmission coefficient with magnitude greater than one, the display must be compressed. The dB difference between calibration setting

Negative Resistance Smith Chart Plot for a GD508A Gunn Diode between 8.1 and 9.0 GHz in 0.1 GHz Steps. Bias; 7 Volts. 10 dB's of attenuation have been applied to the test channel signal.

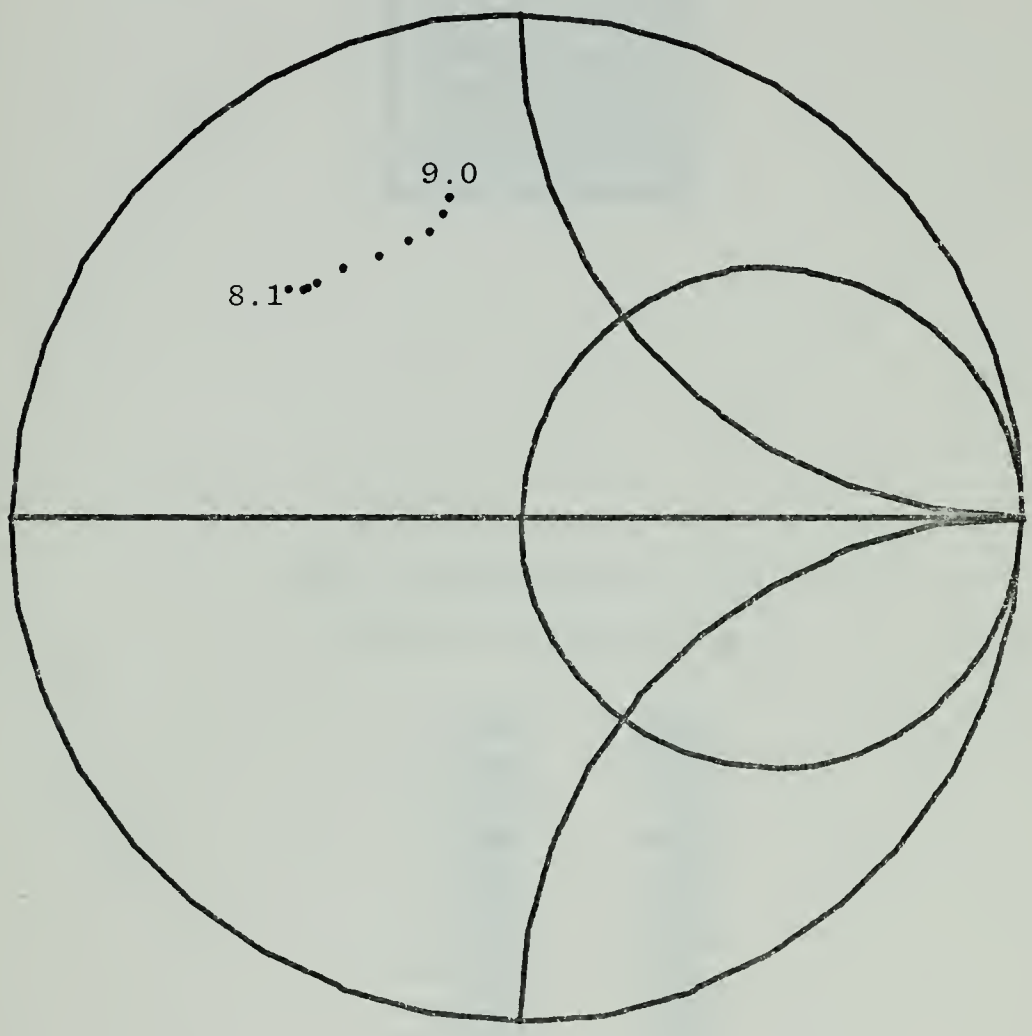


Figure 8a

Frequency in Hz

8.1012[illegible]E08
8.2005[illegible]E08
8.3001[illegible]E09
8.4013[illegible]E08
8.5007[illegible]E09
8.6023[illegible]E09
8.7028[illegible]E08
8.8013[illegible]E08
8.8012[illegible]E08
8.9041[illegible]E08

Real and Imaginary Parts

of Normalized Impedance.

-.246	.386
-.272	.410
-.278	.418
-.285	.437
-.307	.438
-.342	.557
-.380	.628
-.375	.681
-.358	.735
-.329	.768

Figure 8b

Normalized Input Impedance of a JAN2N3866 Transistor Between .5 and 1.0 GHz in .1 GHz Steps. Bias Conditions; V_{CE} = 5 Volts, I_E = 50 ma.

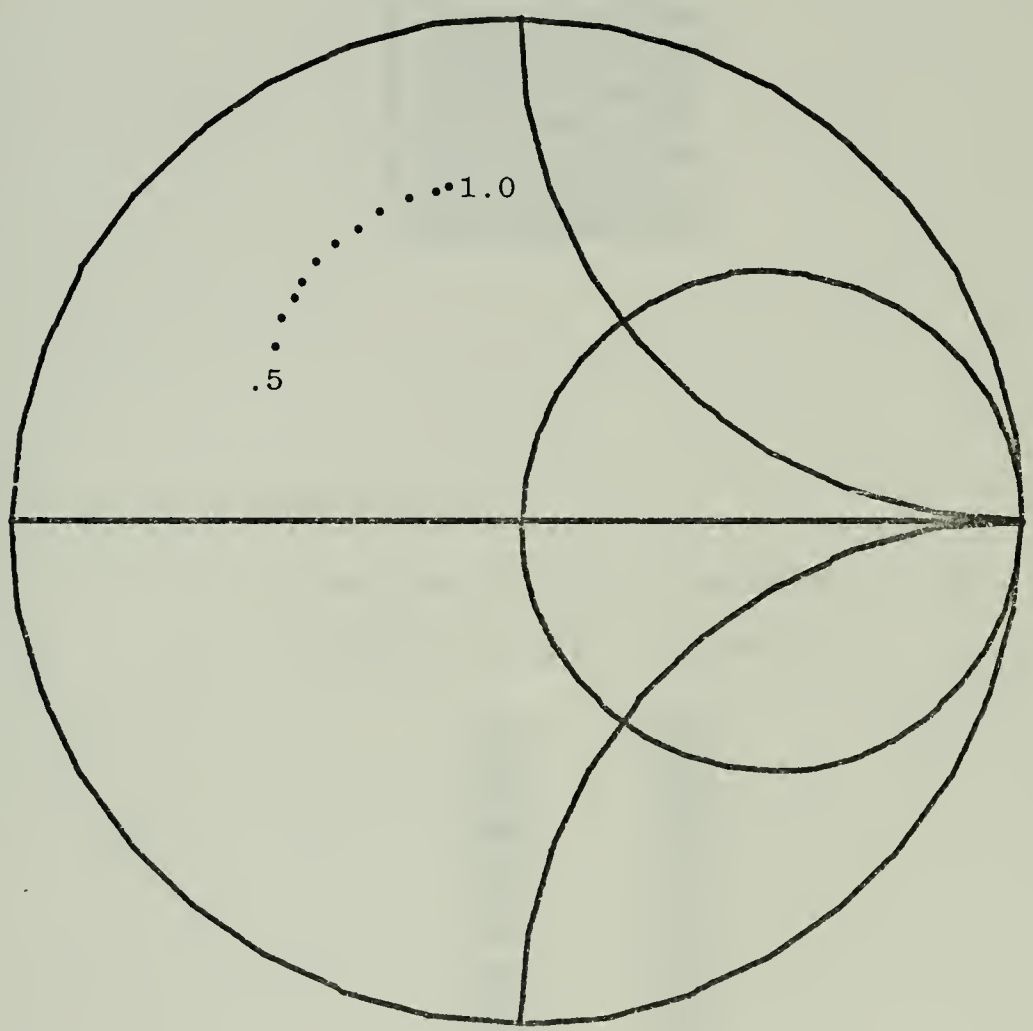


Figure 9a

Frequency in Hz

5.0070000000E+08
5.5000000000E+08
6.0320000000E+08
6.5000000000E+08
7.0000000000E+08
7.5040000000E+08
8.0000000000E+08
8.5000000000E+08
8.0000000000E+08
8.5040000000E+08
1.0000000000E+09

Real and Imaginary Parts of

Normalized Input Impedance.

.274	.304
.282	.355
.282	.388
.258	.429
.254	.472
.257	.518
.267	.571
.283	.627
.277	.684
.283	.753
.287	.785

Figure 9b

and compressed setting is entered into the program by the operator. This is used to calculate the radius of the outer circle.

One other operator entry is required, the absolute value of the x voltage when the analyzer is calibrated to a short circuit. This is used to normalize x and y voltage readings to one so that 449 plotter increments will define maximum radius regardless of actual maximum radius value. Generally, this normalizing voltage is 2.1. It should be noted that regardless of the test channel dB setting, either before or after display compression or expansion, this voltage is always produced as the maximum useable x deflection voltage.

Figure 10 shows a typical output.

D. SCHOTTKY BARRIER CAPACITANCE - PLOTTING AND LISTING

This program calculates and plots the depletion capacitance of a Schottky diode as a function of reverse bias. The Smith Chart program is used to store and plot reflection measurement points of a reverse biased Schottky diode. The diode program is then loaded into memory where the Smith Chart program is located. This replaces the Smith Chart program with the diode program. The raw data stored in memory is not disturbed by this reloading.

The diode program draws and labels a rectangular coordinate system for quadrant II. The operator then enters the bias voltages in the order used. As a voltage is entered, depletion capacitance is calculated and stored with it. The program compares the voltages and uses the largest to scale

Forward Voltage Transfer Coefficient (S_{21}) of a JAN2N3866 Transistor Between .5 and 1.0 GHz in .1 GHz Steps. Bias conditions; V_{CE} = 5 Volts, I_E = 50 ma. 6 dB's of attenuation have been applied to the test channel signal.

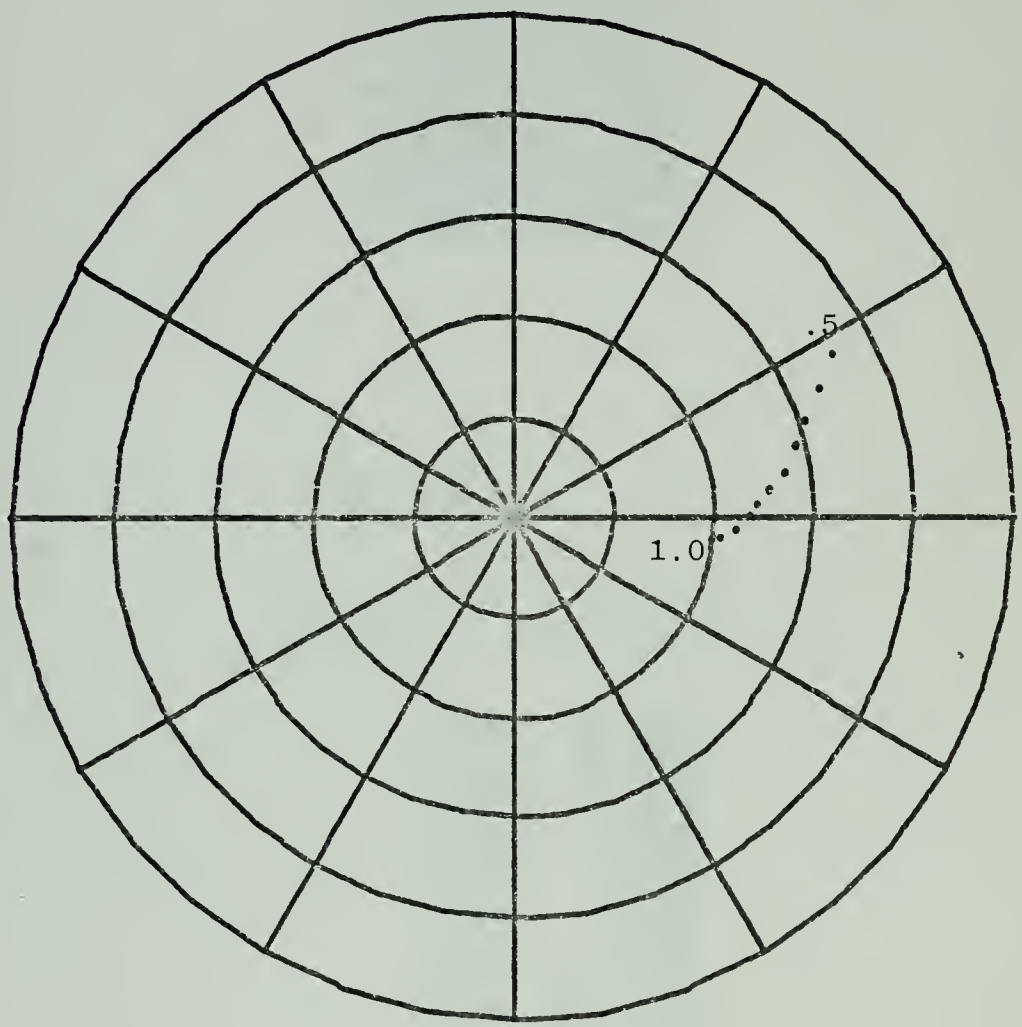
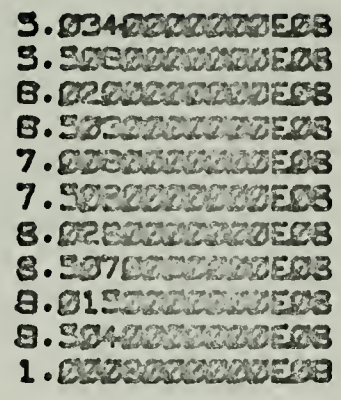


Figure 10a

Frequency in Hz



Magnitude and Angle of S_{21}

1.433	27.580
1.320	23.171
1.218	18.630
1.152	14.888
1.078	8.470
1.024	6.138
.844	2.584
.807	358.780
.854	355.801
.782	352.827
.754	351.012

Figure 10b

the x axis. Likewise, the largest capacitance is used to scale the y axis to either 2.5 or 5 picofarads. The points are plotted and tabulated in the order taken.

Bias voltage can be applied to the diode in any order desired, but it must be entered into the program in that same order.

Figure 11 shows a typical output.

Reverse Biased Schottky Diode at 1.0 GHz. Bias; 0 to -5 Volts in .5 Volt Increments.

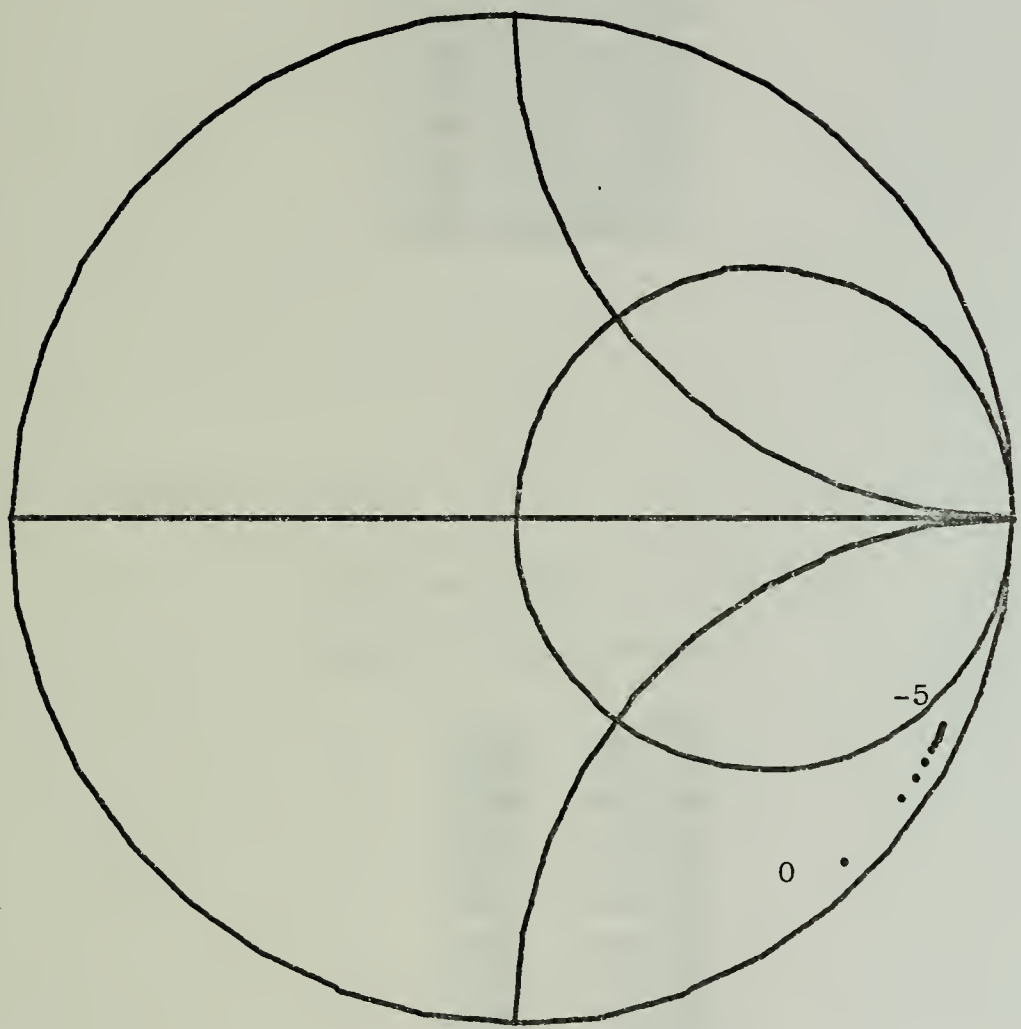


Figure 11a

Frequency in Hz

1.0017E08
1.0017E08
1.0017E08
1.0017E08
1.0017E08
1.0017E08
1.0017E08
1.0017E08
1.0017E08
1.0017E08
1.0017E08
1.0017E08

Real and Imaginary Parts of

Normalized Impedance.

.180	-2.378
.259	-3.138
.302	-3.461
.349	-3.737
.381	-3.871
.415	-4.107
.440	-4.252
.467	-4.381
.488	-4.442
.508	-4.538
.510	-4.613

Figure 11b

Depletion Capacitance Versus Reverse Bias Voltage for Schottky Diode.

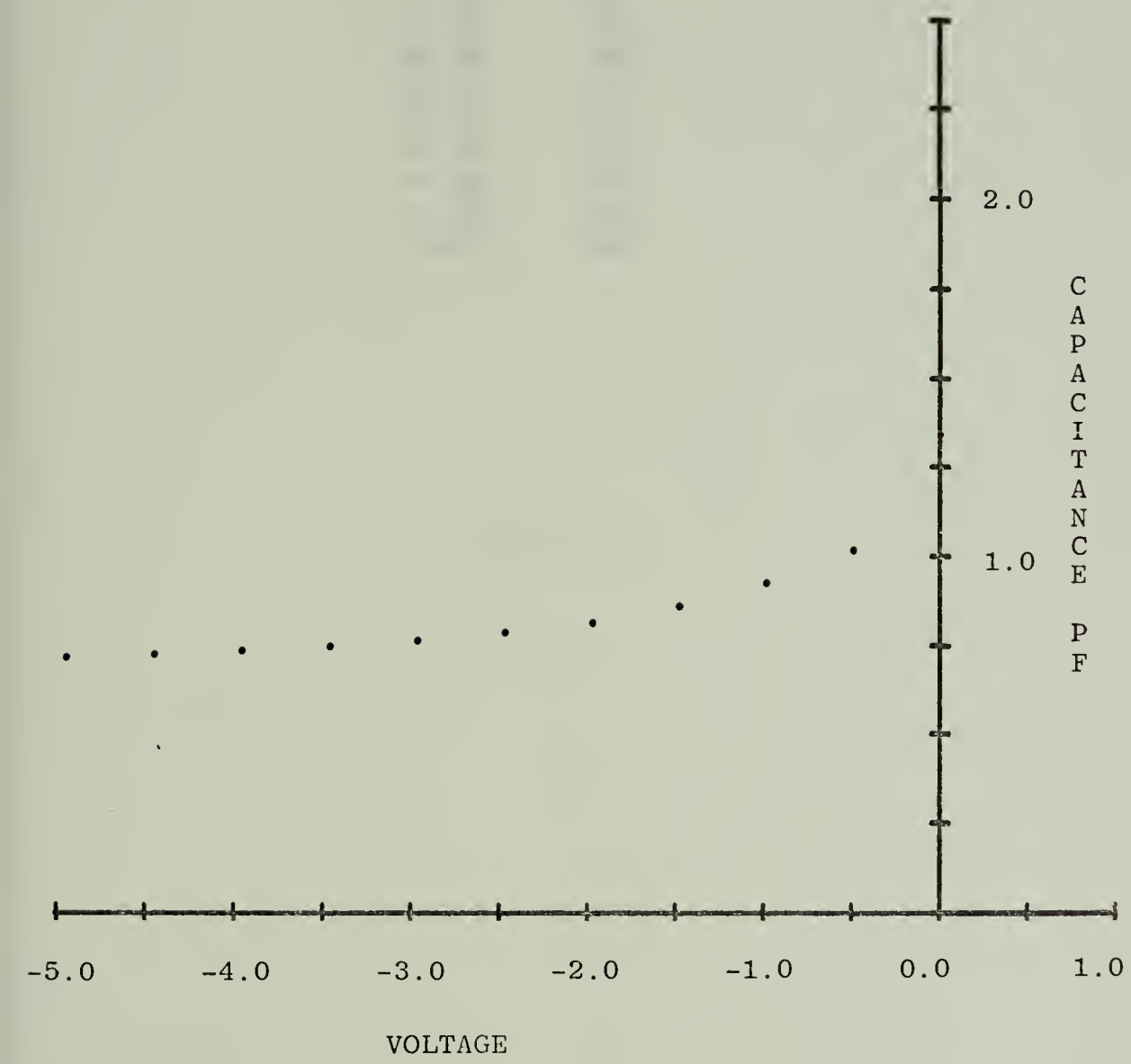


Figure 11c

VOLTS	PICOFARADS
0.00	1.33
-.50	1.01
-1.00	.81
-1.50	.65
-2.00	.60
-2.50	.77
-3.00	.74
-3.50	.72
-4.00	.71
-4.50	.69
-5.00	.68

Figure 11d

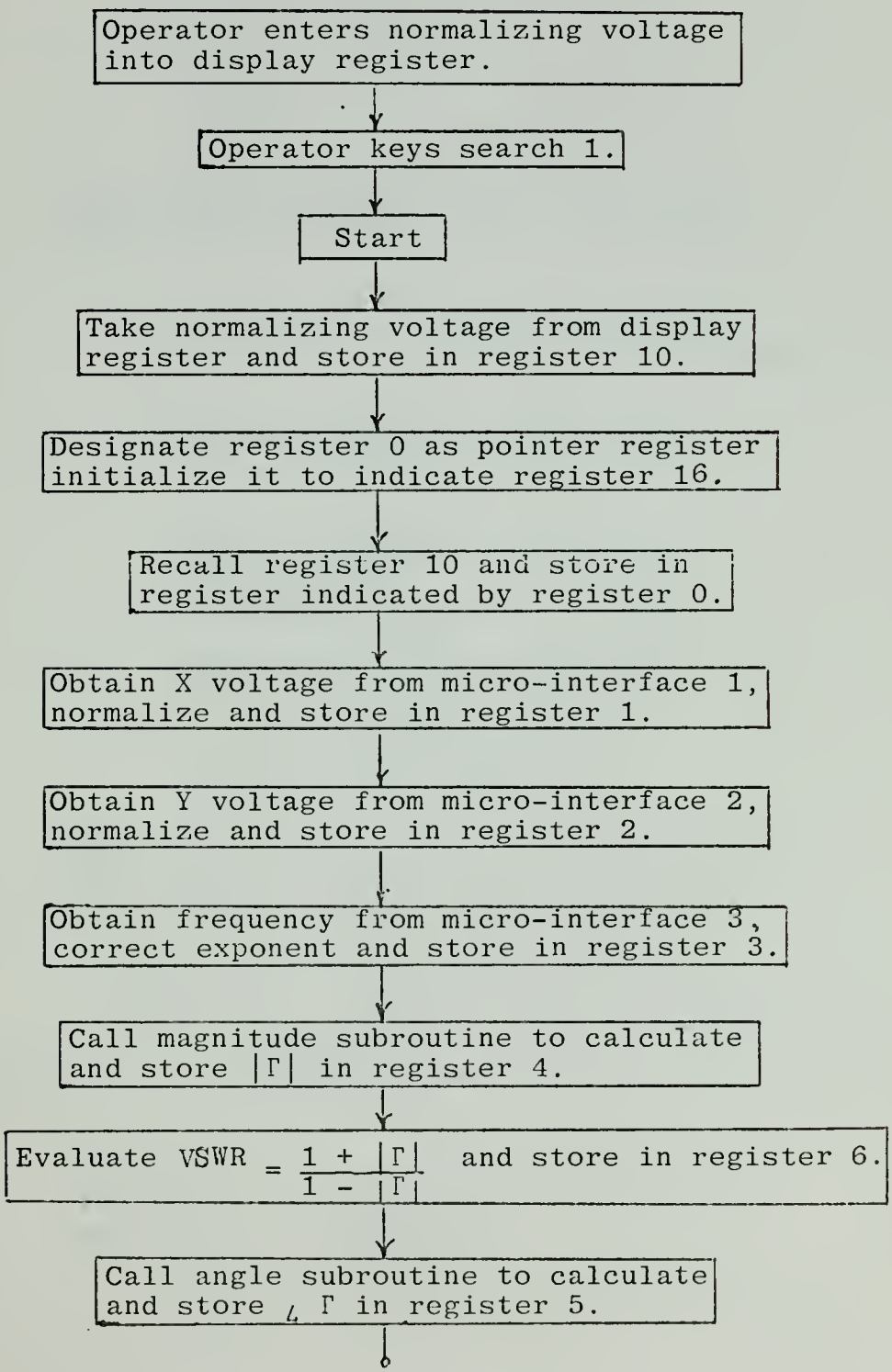
VI. CONCLUSIONS

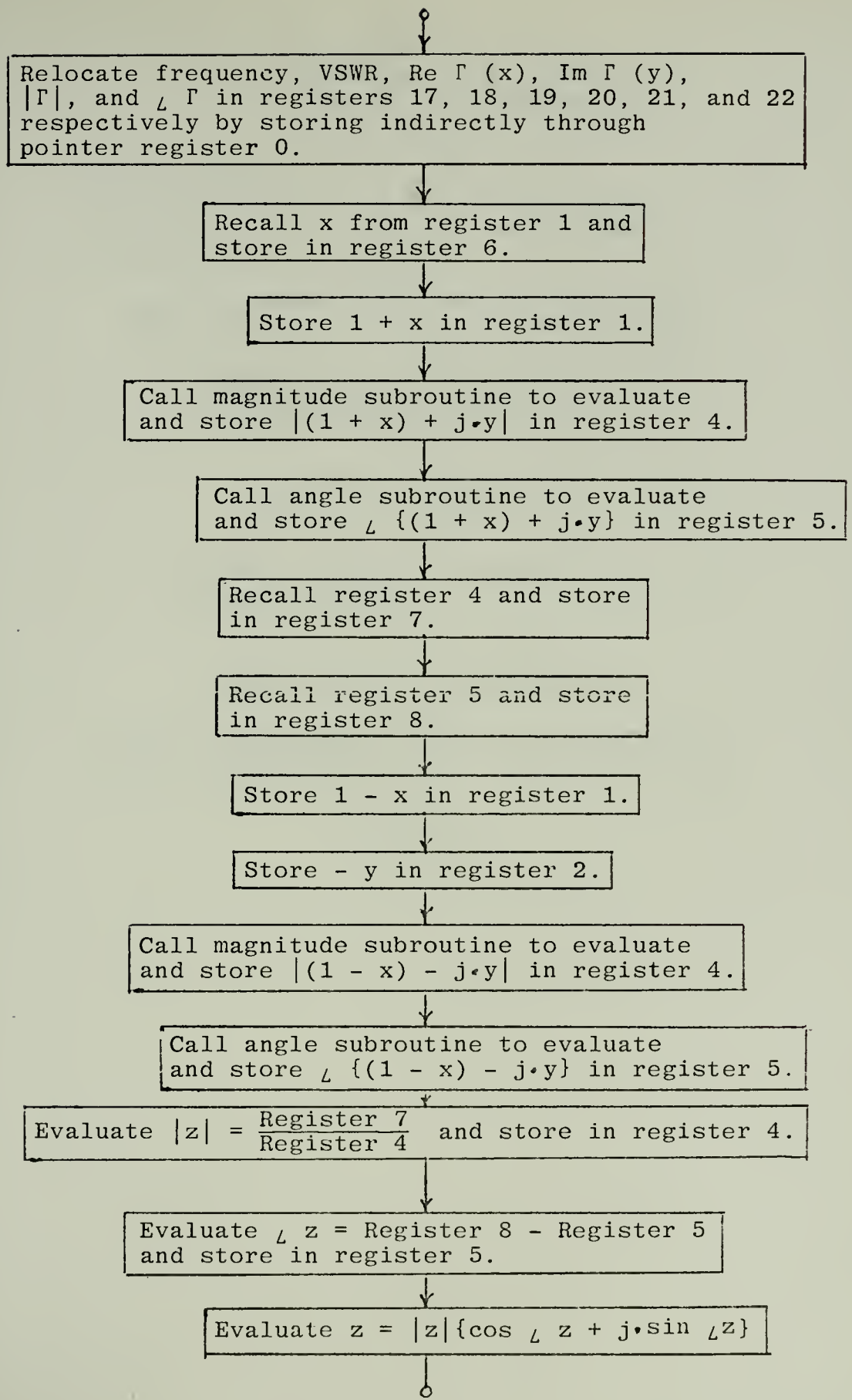
The feasibility of calculator-aided microwave network analysis has been demonstrated. Data reduction program implementation requires more than casual familiarity with the programmable calculator.

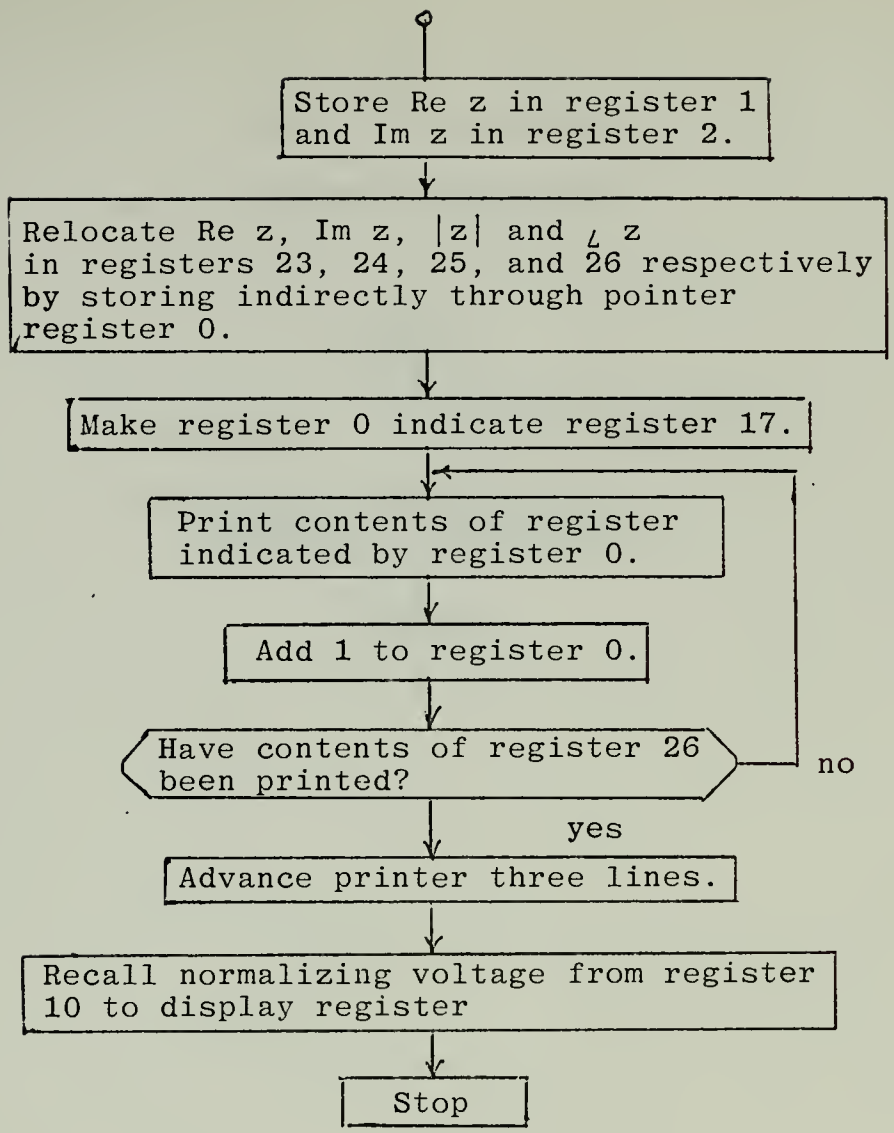
VII. RECOMMENDATIONS

A digital to analog interface from the calculator to the sweep oscillator should be acquired. This would allow frequency selection under program control, thus making the analyzer-calculator system fully automatic.

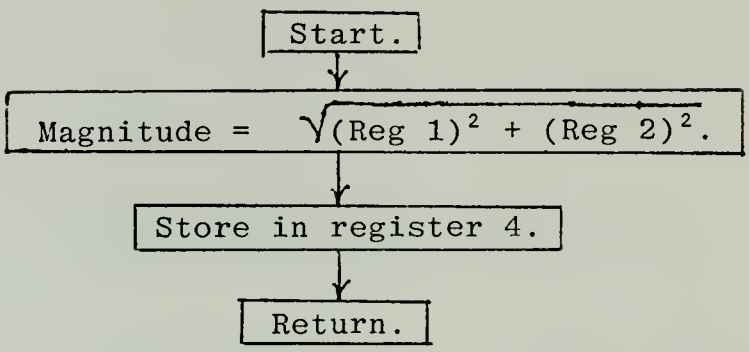
APPENDIX A: S_{11}/S_{22}-PRINTING FLOWCHART



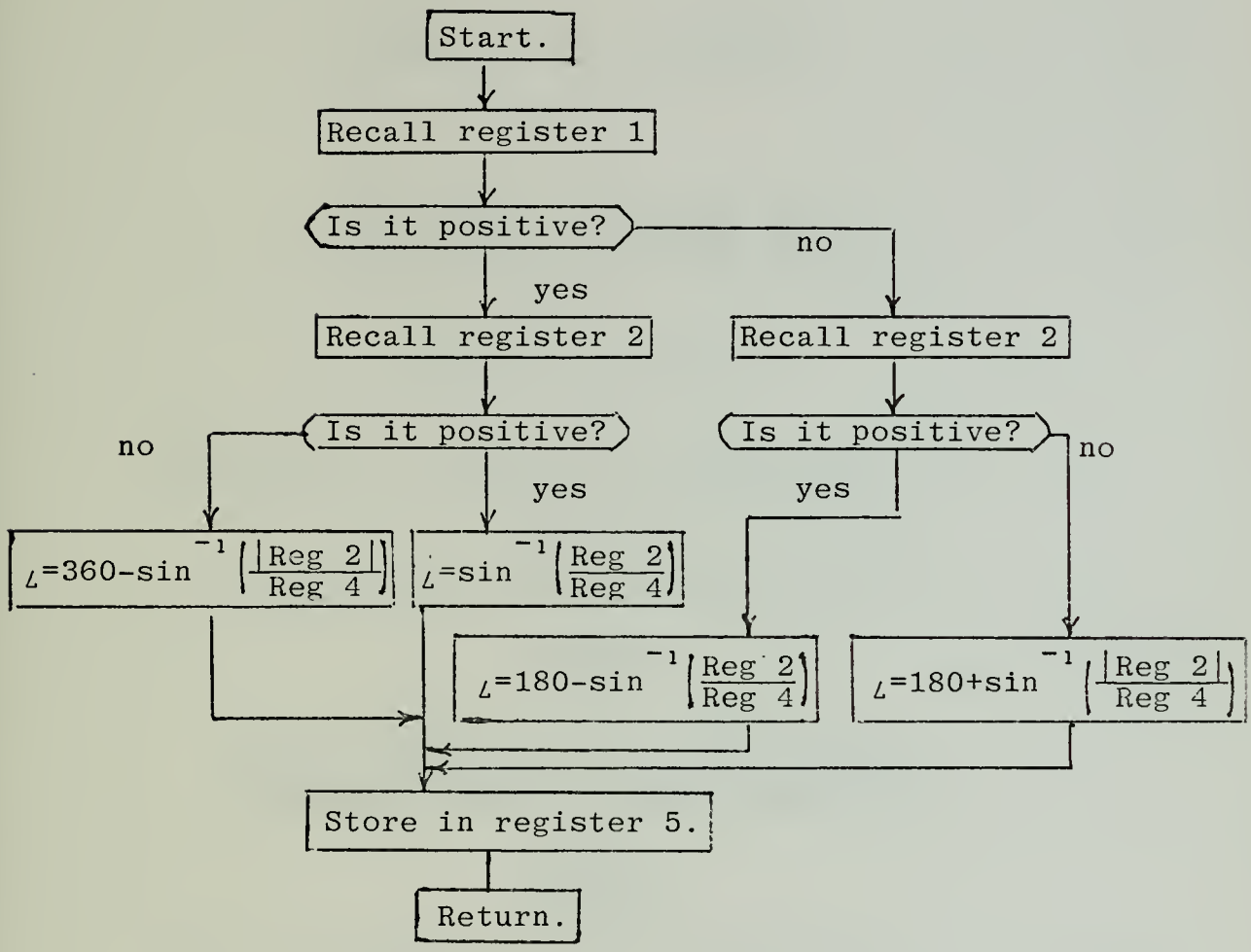

Relocate frequency, VSWR, Re Γ (x), Im Γ (y), |Γ|, and ∠ Γ in registers 17, 18, 19, 20, 21, and 22 respectively by storing indirectly through pointer register 0.
Recall x from register 1 and store in register 6.
Store 1 + x in register 1.
Call magnitude subroutine to evaluate and store |(1 + x) + j•y| in register 4.
Call angle subroutine to evaluate and store ∠ {(1 + x) + j•y} in register 5.
Recall register 4 and store in register 7.
Recall register 5 and store in register 8.
Store 1 - x in register 1.
Store - y in register 2.
Call magnitude subroutine to evaluate and store |(1 - x) - j•y| in register 4.
Call angle subroutine to evaluate and store ∠ {(1 - x) - j•y} in register 5.
Evaluate |z| = Register 7 / Register 4 and store in register 4.
Evaluate ∠ z = Register 8 - Register 5 and store in register 5.
Evaluate z = |z|{cos ∠ z + j•sin ∠z}


Store Re z in register 1
and Im z in register 2.
Relocate Re z, Im z, |z| and ∠ z
in registers 23, 24, 25, and 26 respectively
by storing indirectly through pointer
register 0.
Make register 0 indicate register 17.
Print contents of register
indicated by register 0.
Add 1 to register 0.
Have contents of register 26
been printed?
no
yes
Advance printer three lines.
Recall normalizing voltage from register
10 to display register
Stop

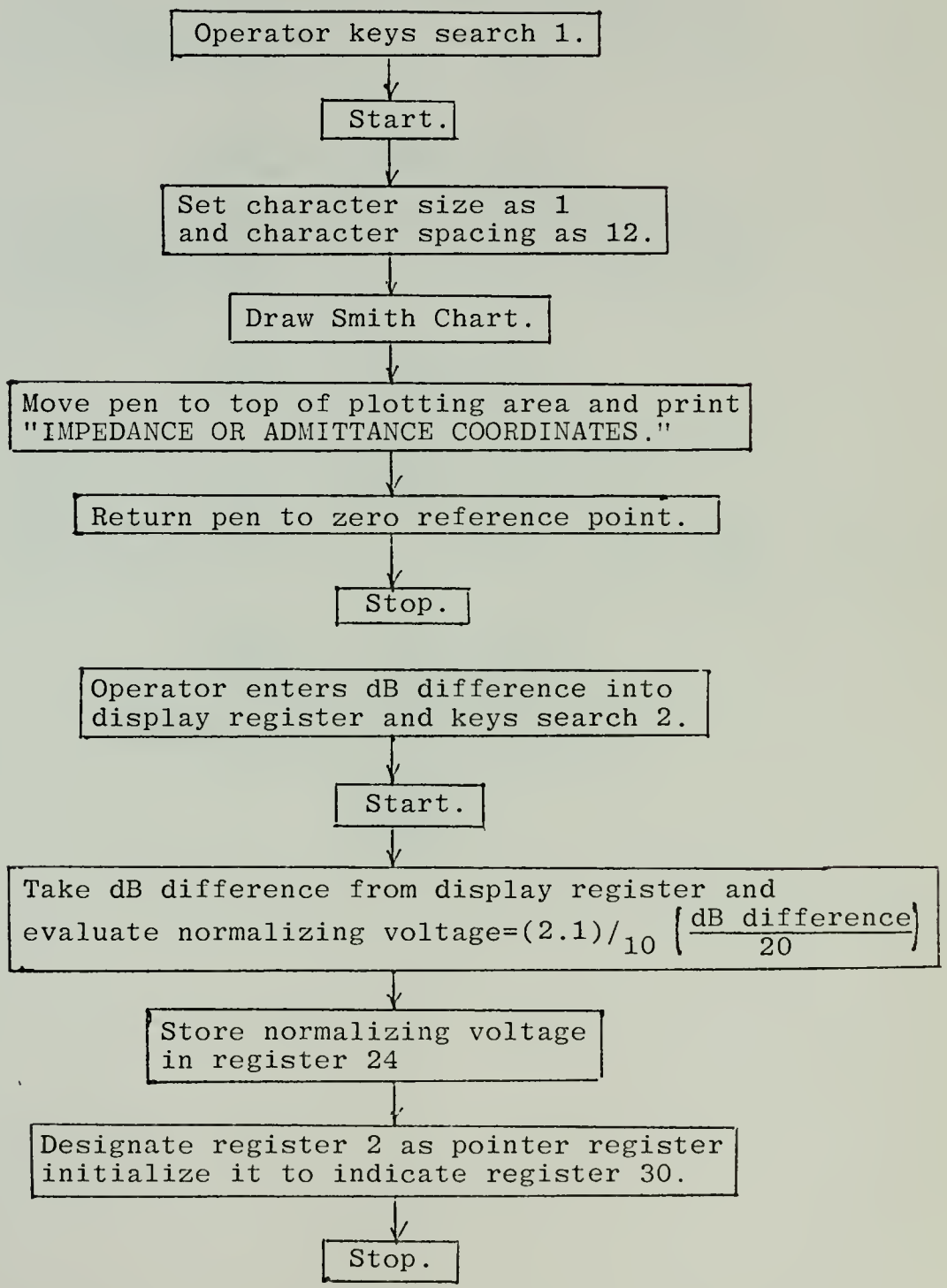
MAGNITUDE SUBROUTINE

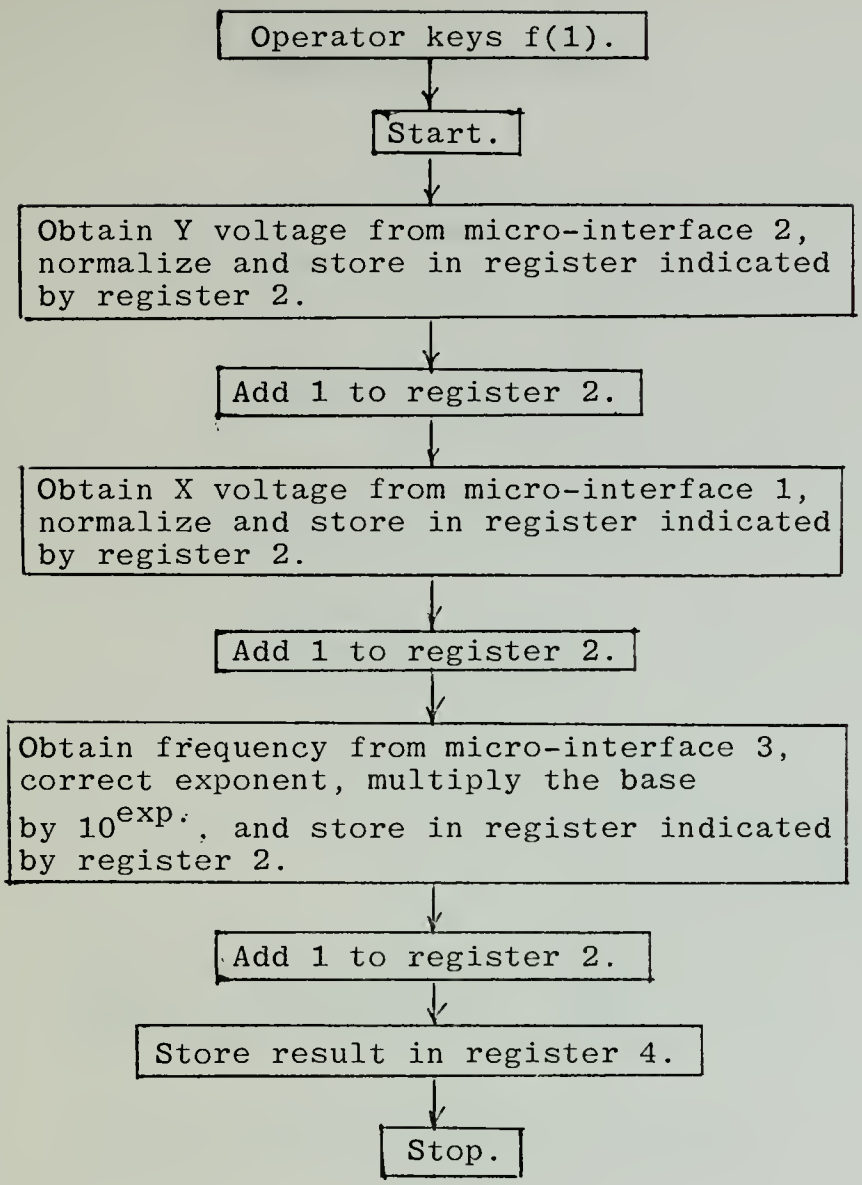


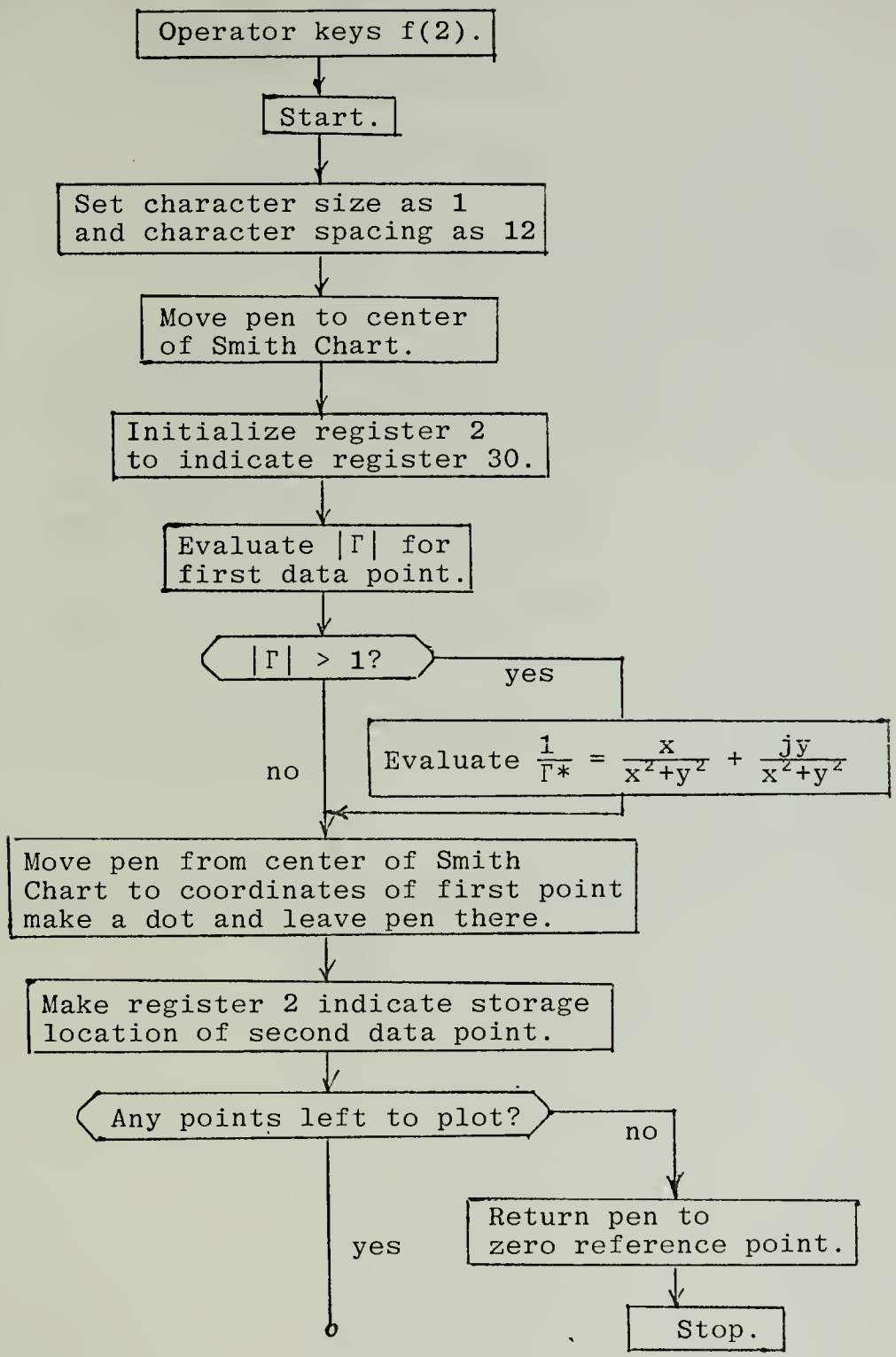
ANGLE SUBROUTINE

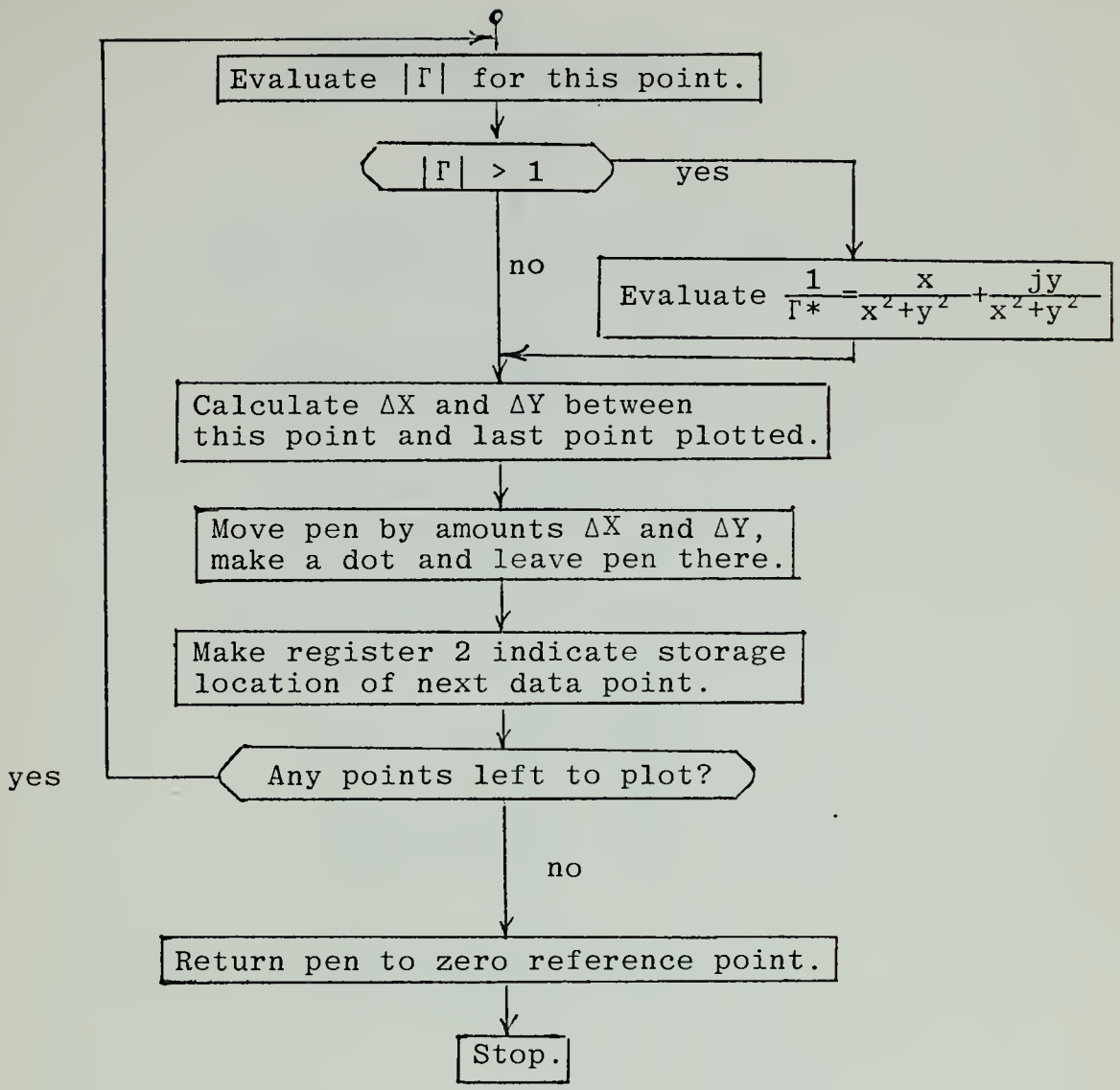


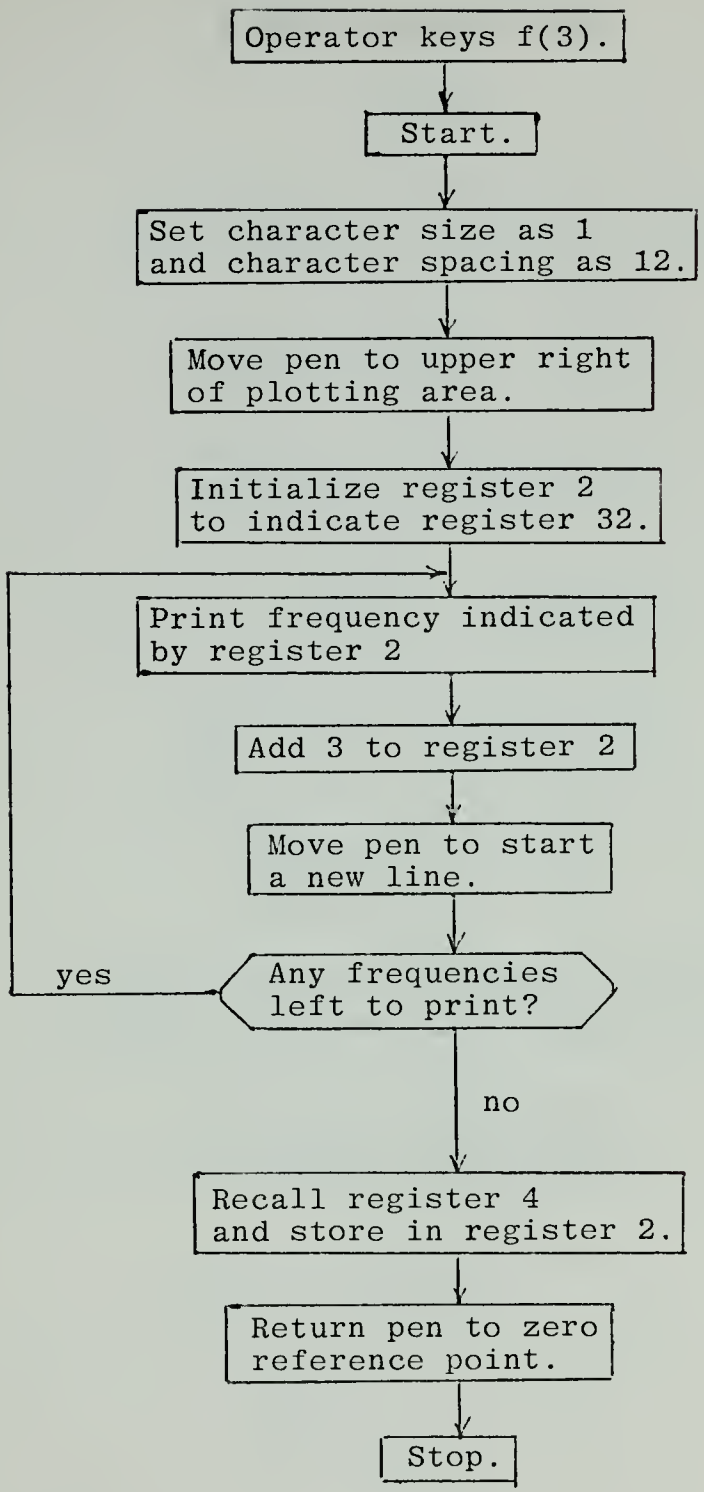
APPENDIX B: SMITH CHART-PLOTTING AND LISTING FLOWCHART

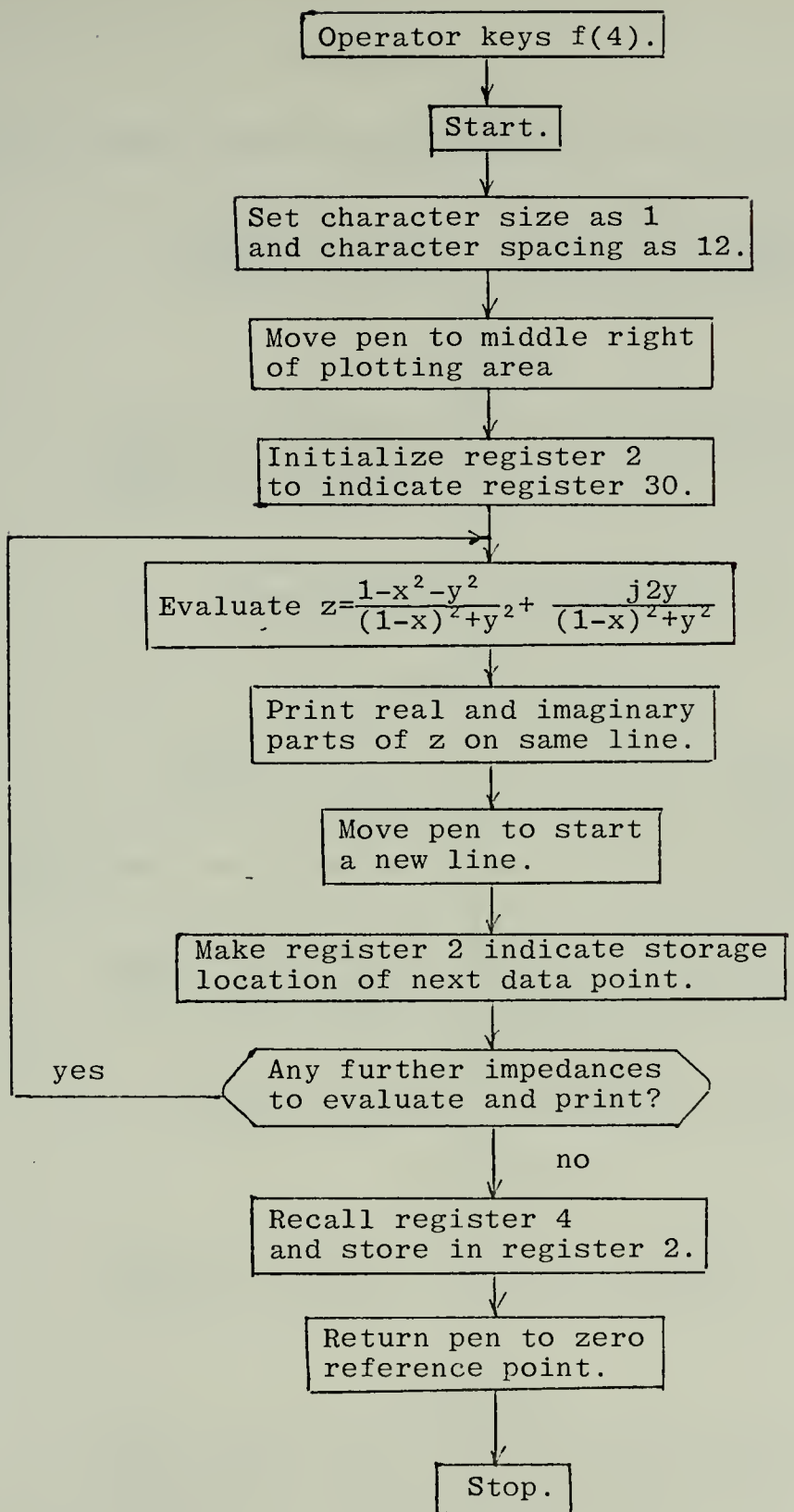



Operator keys f(1).
Start.
Obtain Y voltage from micro-interface 2, normalize and store in register indicated by register 2.
Add 1 to register 2.
Obtain X voltage from micro-interface 1, normalize and store in register indicated by register 2.
Add 1 to register 2.
Obtain frequency from micro-interface 3, correct exponent, multiply the base by $10^{exp.}$, and store in register indicated by register 2.
Add 1 to register 2.
Store result in register 4.
Stop.


Operator keys f(2).
Start.
Set character size as 1 and character spacing as 12
Move pen to center of Smith Chart.
Initialize register 2 to indicate register 30.
Evaluate |Γ| for first data point.
|Γ| > 1?
yes
no
Evaluate 1/Γ* = x/(x²+y²) + jy/(x²+y²)
Move pen from center of Smith Chart to coordinates of first point make a dot and leave pen there.
Make register 2 indicate storage location of second data point.
Any points left to plot?
no
yes
Return pen to zero reference point.
Stop.

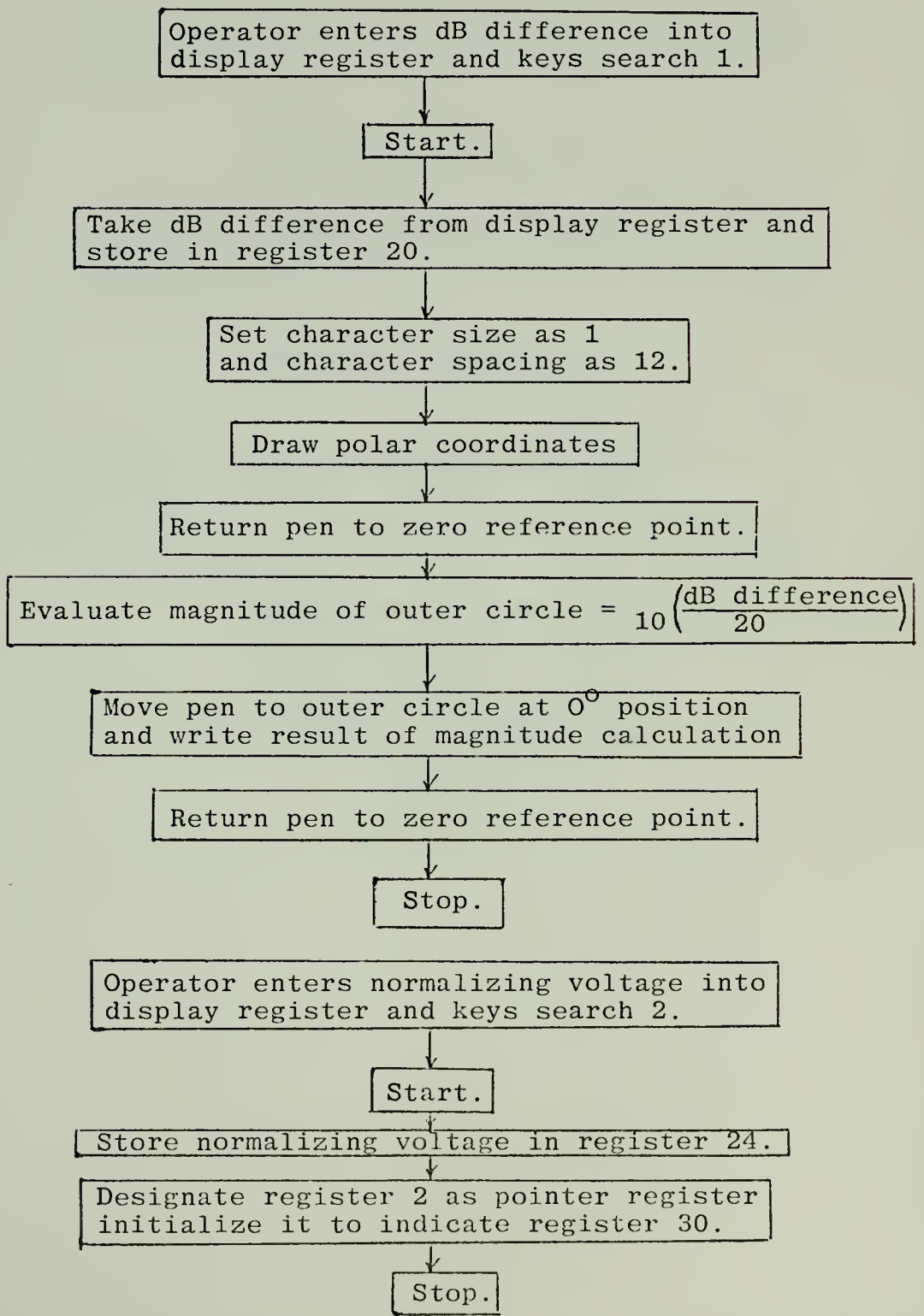

Evaluate |Γ| for this point.
|Γ| > 1
yes
no
Evaluate $\frac{1}{\Gamma^*} = \frac{x}{x^2+y^2} + \frac{jy}{x^2+y^2}$
Calculate ΔX and ΔY between this point and last point plotted.
Move pen by amounts ΔX and ΔY, make a dot and leave pen there.
Make register 2 indicate storage location of next data point.
Any points left to plot?
yes
no
Return pen to zero reference point.
Stop.

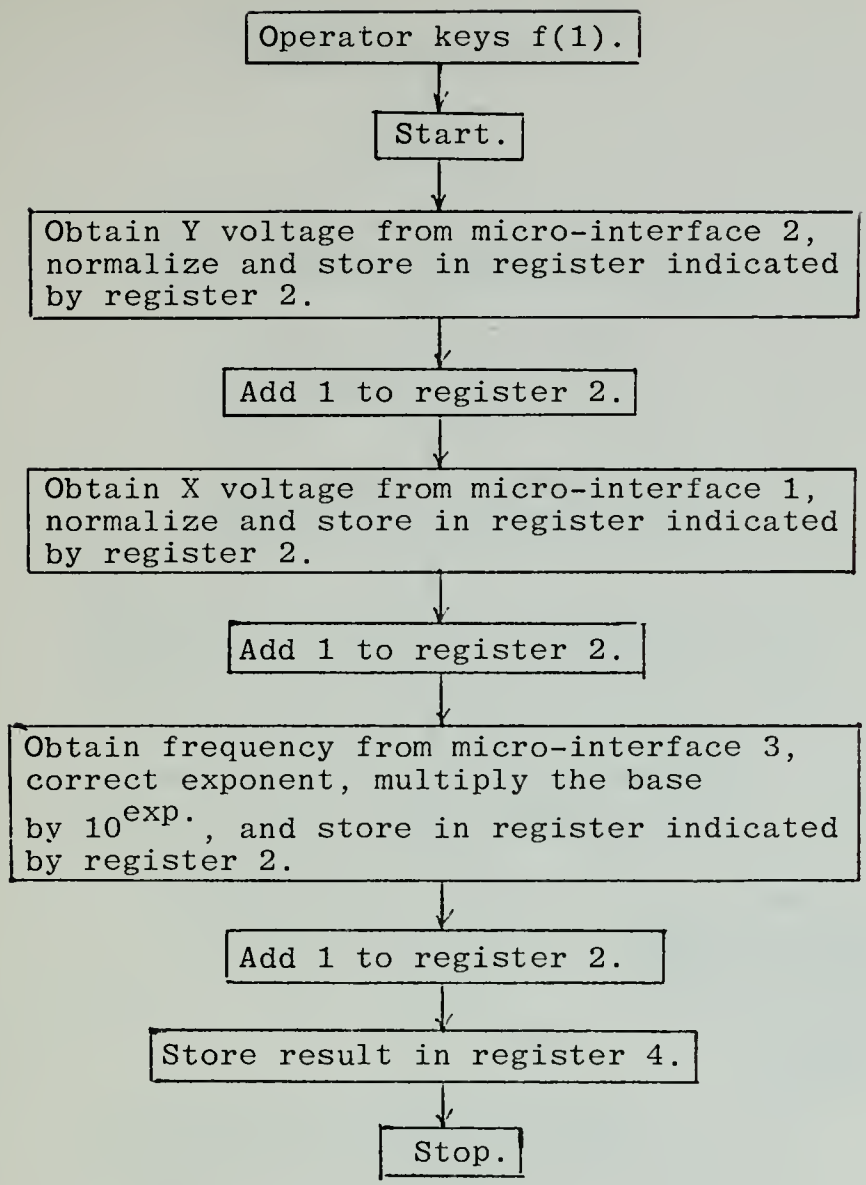

Operator keys f(3).
Start.
Set character size as 1 and character spacing as 12.
Move pen to upper right of plotting area.
Initialize register 2 to indicate register 32.
Print frequency indicated by register 2
Add 3 to register 2
Move pen to start a new line.
Any frequencies left to print?
yes
no
Recall register 4 and store in register 2.
Return pen to zero reference point.
Stop.

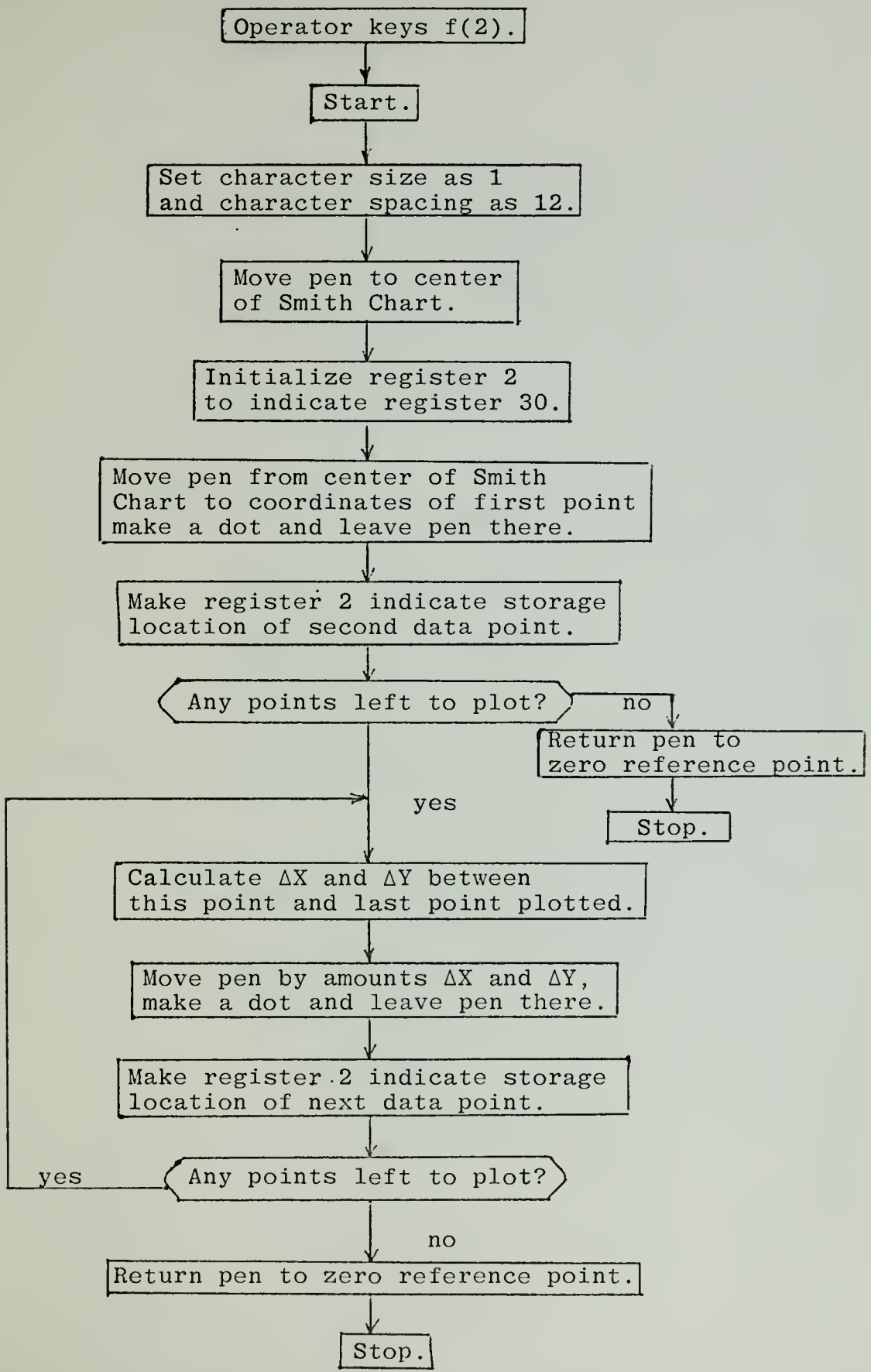

Operator keys f(4).
Start.
Set character size as 1 and character spacing as 12.
Move pen to middle right of plotting area
Initialize register 2 to indicate register 30.
Evaluate $z=\frac{1-x^2-y^2}{(1-x)^2+y^2}+\frac{j2y}{(1-x)^2+y^2}$
Print real and imaginary parts of z on same line.
Move pen to start a new line.
Make register 2 indicate storage location of next data point.
Any further impedances to evaluate and print?
yes
no
Recall register 4 and store in register 2.
Return pen to zero reference point.
Stop.

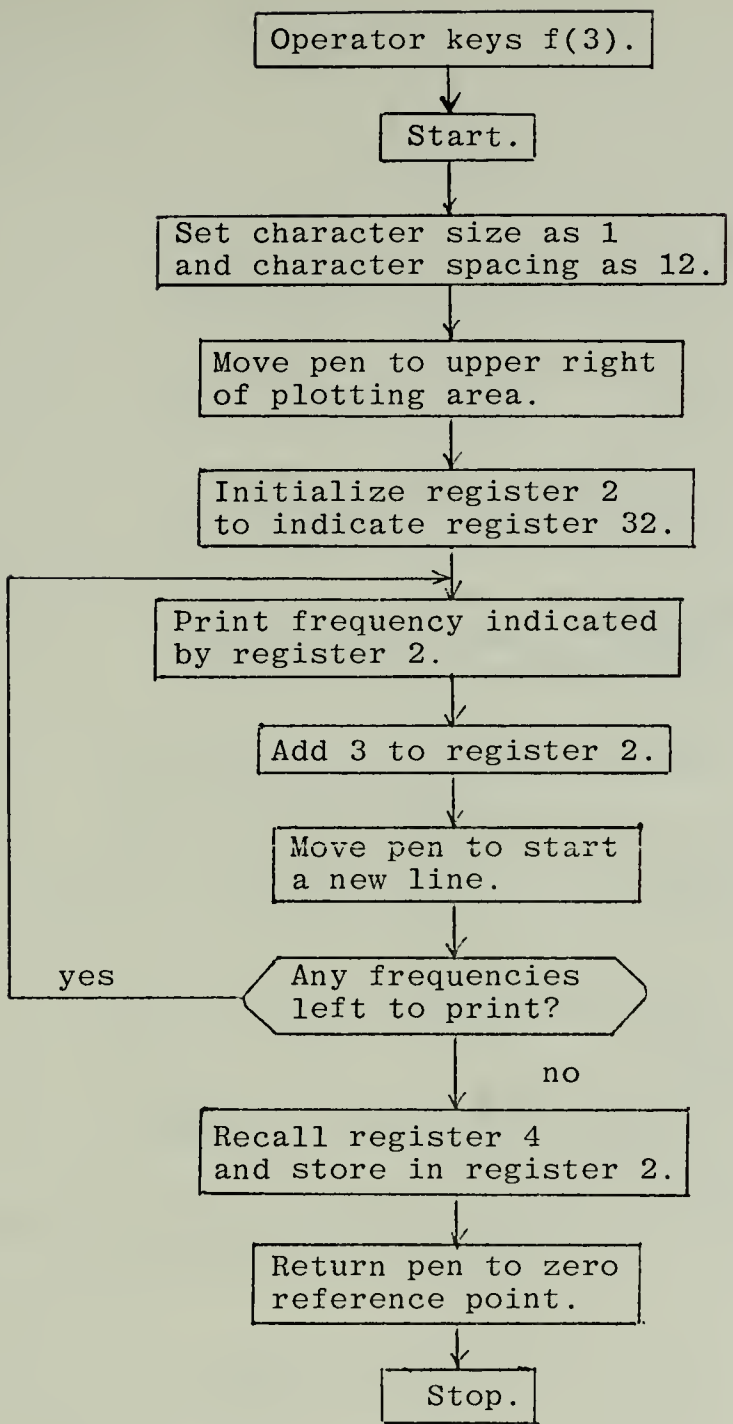
APPENDIX C

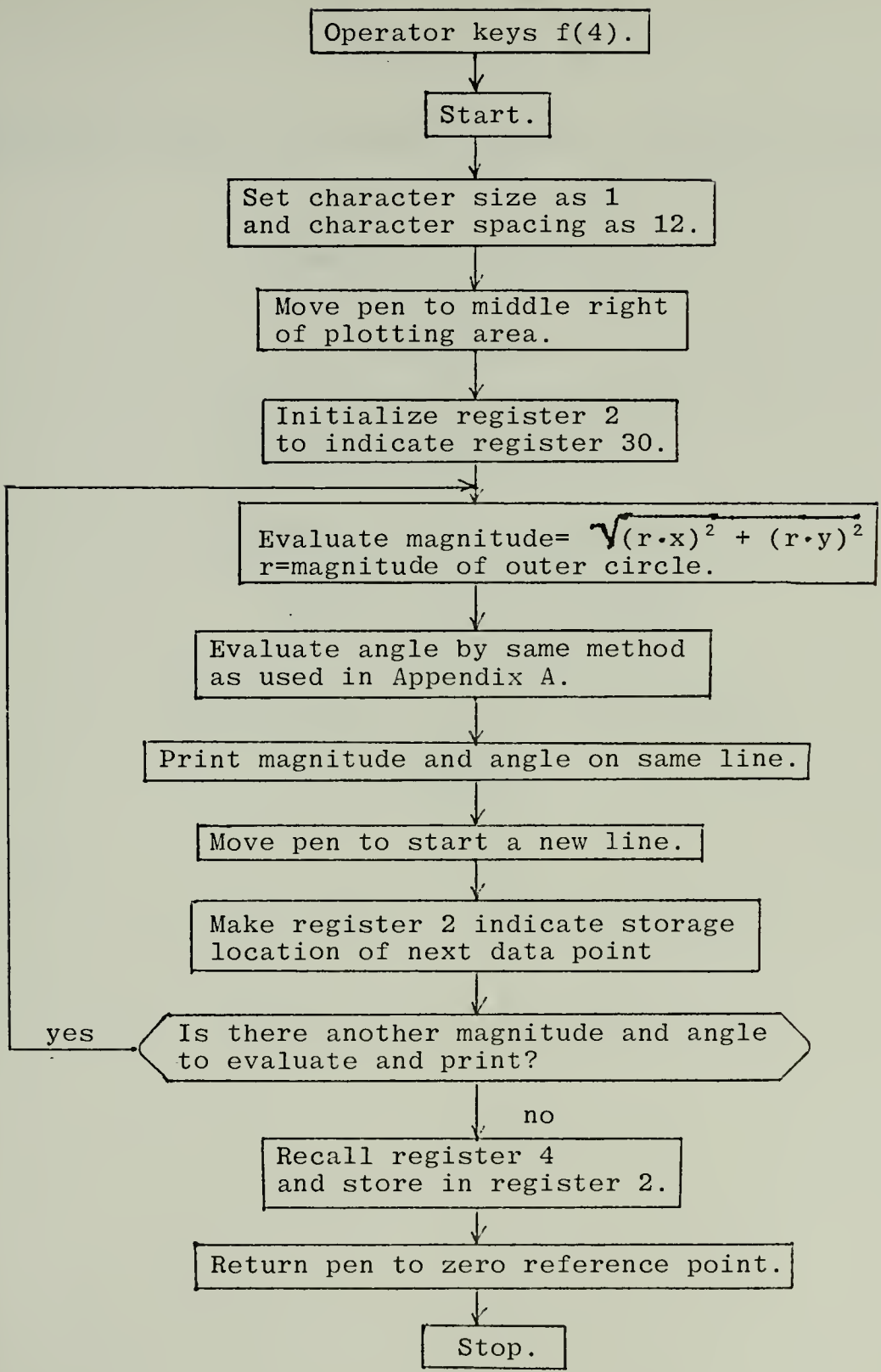
S_{12}/S_{21} POLAR COORDINATES-PLOTTING AND LISTING FLOWCHART



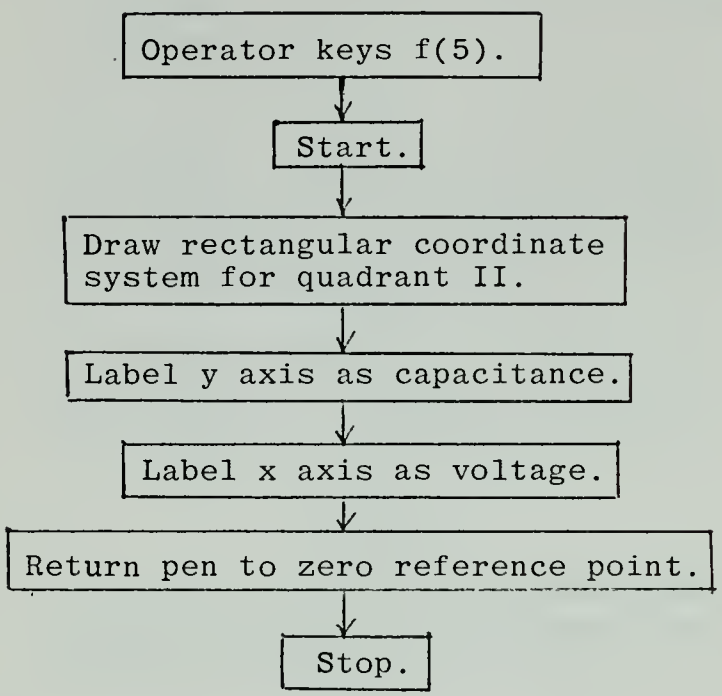

Operator keys f(1).
Start.
Obtain Y voltage from micro-interface 2, normalize and store in register indicated by register 2.
Add 1 to register 2.
Obtain X voltage from micro-interface 1, normalize and store in register indicated by register 2.
Add 1 to register 2.
Obtain frequency from micro-interface 3, correct exponent, multiply the base by 10^exp., and store in register indicated by register 2.
Add 1 to register 2.
Store result in register 4.
Stop.

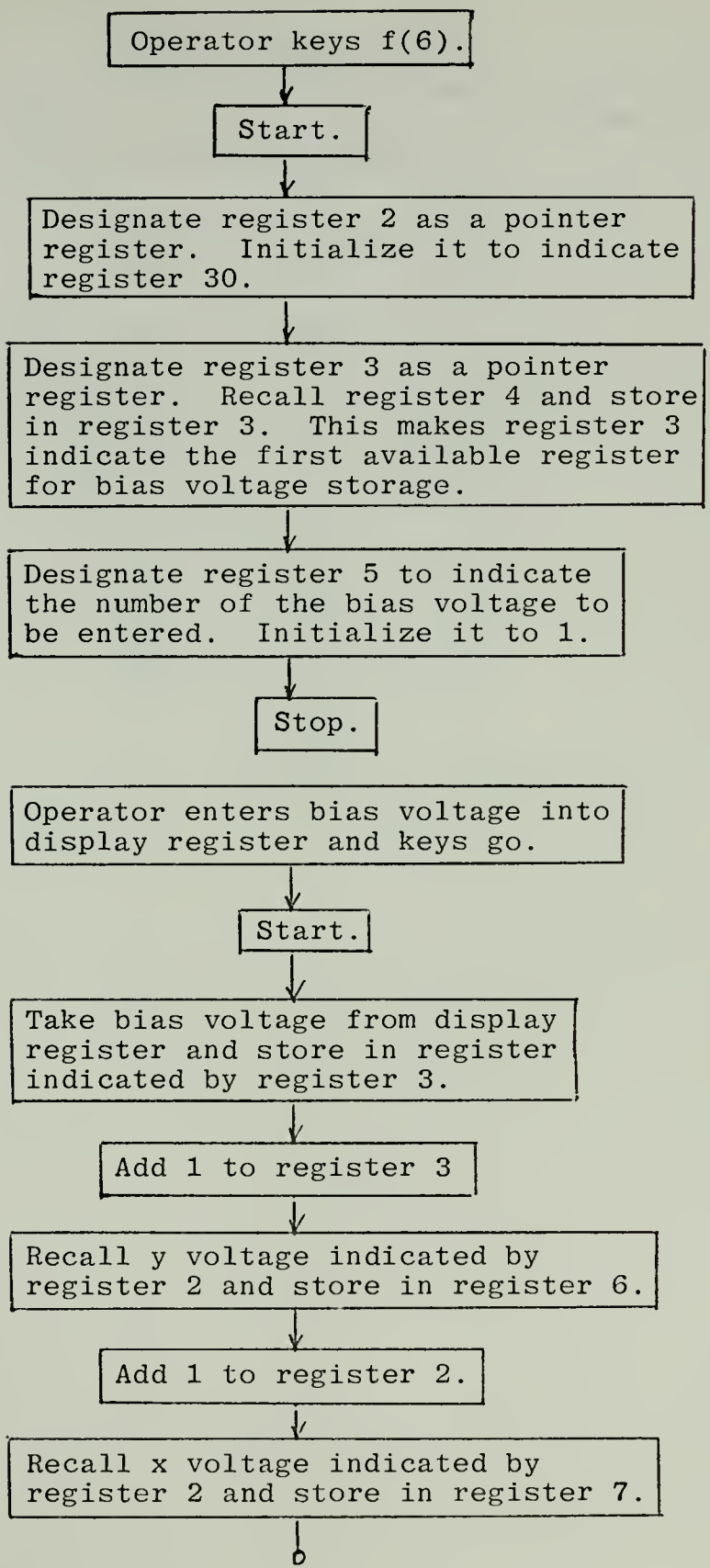

Operator keys f(2).
Start.
Set character size as 1 and character spacing as 12.
Move pen to center of Smith Chart.
Initialize register 2 to indicate register 30.
Move pen from center of Smith Chart to coordinates of first point make a dot and leave pen there.
Make register 2 indicate storage location of second data point.
Any points left to plot?
no
Return pen to zero reference point.
Stop.
yes
Calculate ΔX and ΔY between this point and last point plotted.
Move pen by amounts ΔX and ΔY, make a dot and leave pen there.
Make register 2 indicate storage location of next data point.
yes
Any points left to plot?
no
Return pen to zero reference point.
Stop.

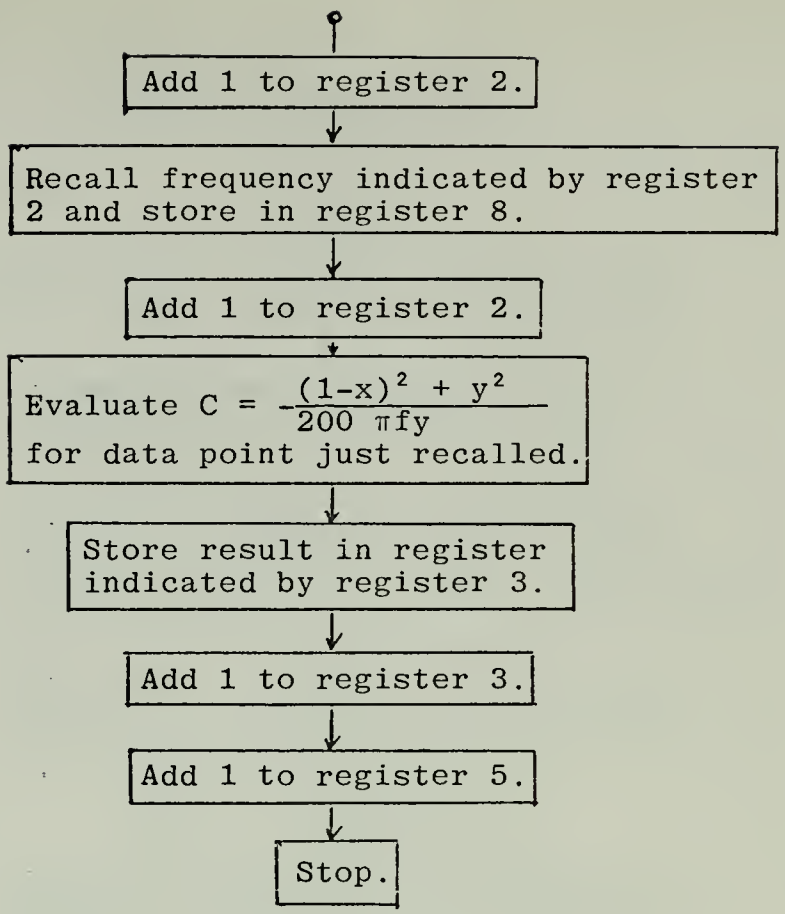

Operator keys f(3).
Start.
Set character size as 1 and character spacing as 12.
Move pen to upper right of plotting area.
Initialize register 2 to indicate register 32.
Print frequency indicated by register 2.
Add 3 to register 2.
Move pen to start a new line.
Any frequencies left to print?
yes
no
Recall register 4 and store in register 2.
Return pen to zero reference point.
Stop.

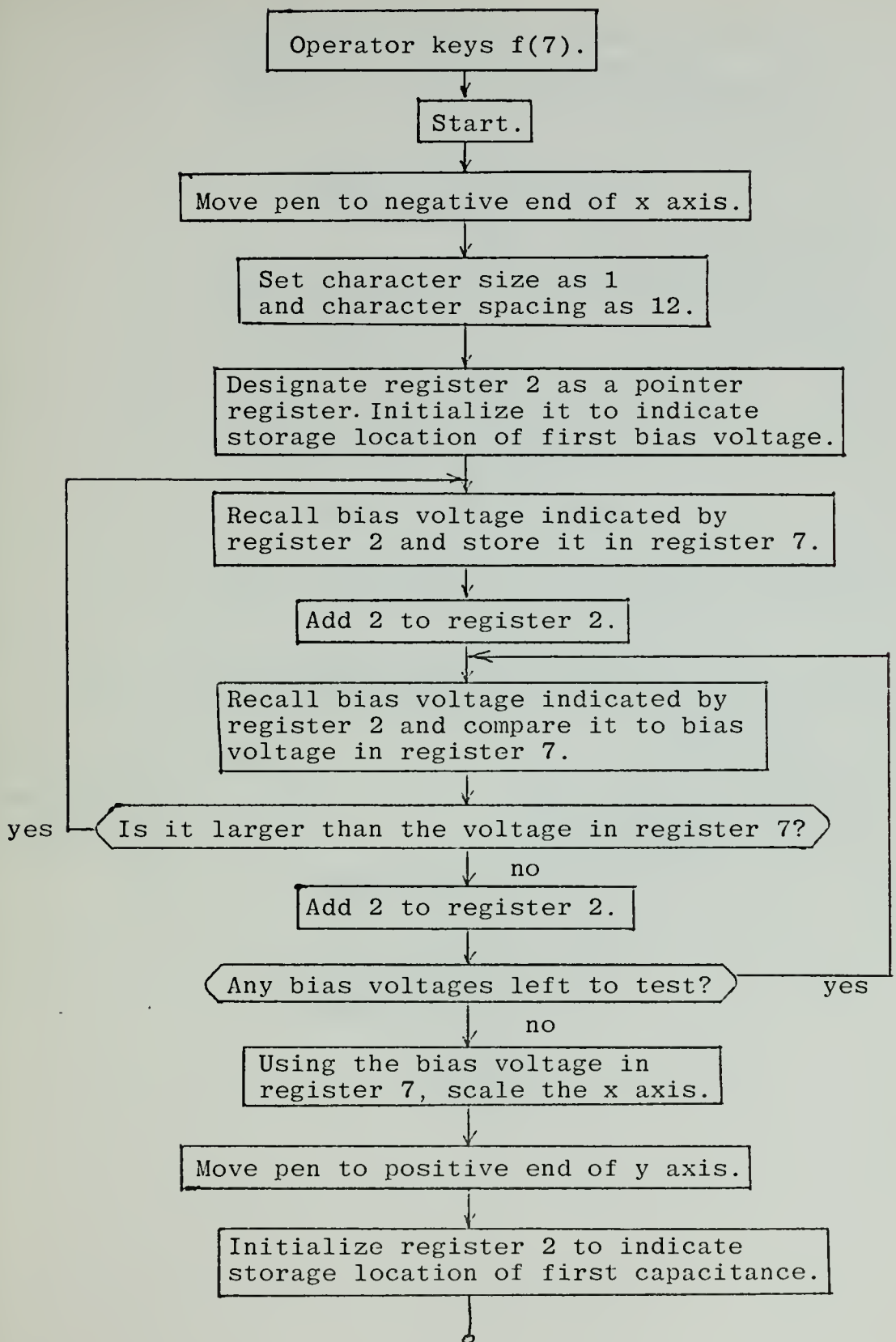

Operator keys f(4).
Start.
Set character size as 1
and character spacing as 12.
Move pen to middle right
of plotting area.
Initialize register 2
to indicate register 30.
Evaluate magnitude= $\sqrt{(r \cdot x)^2 + (r \cdot y)^2}$
r=magnitude of outer circle.
Evaluate angle by same method
as used in Appendix A.
Print magnitude and angle on same line.
Move pen to start a new line.
Make register 2 indicate storage
location of next data point
yes
Is there another magnitude and angle
to evaluate and print?
no
Recall register 4
and store in register 2.
Return pen to zero reference point.
Stop.

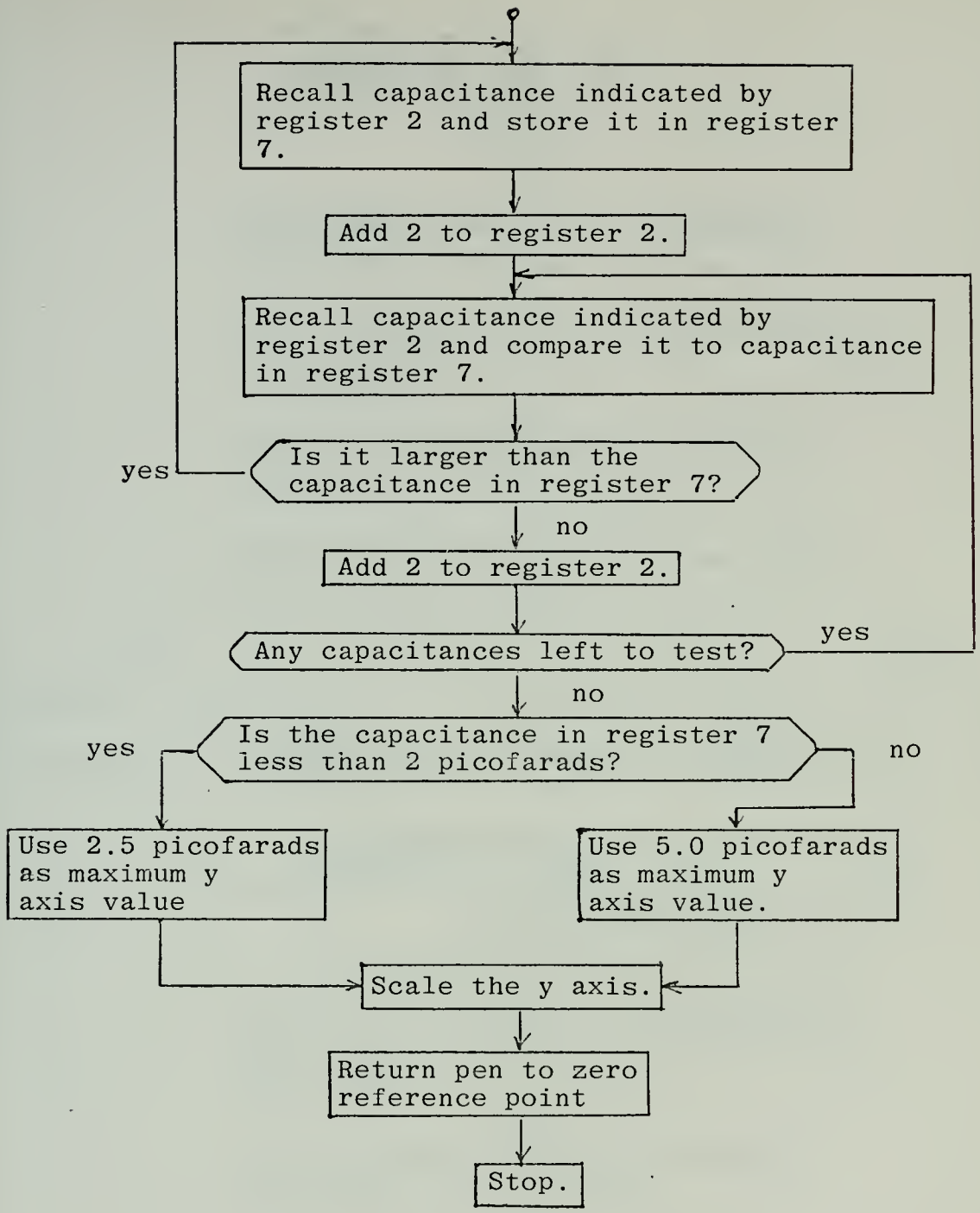
APPENDIX D
SCHOTTKY BARRIER CAPACITANCE-PLOTTING AND LISTING FLOWCHART

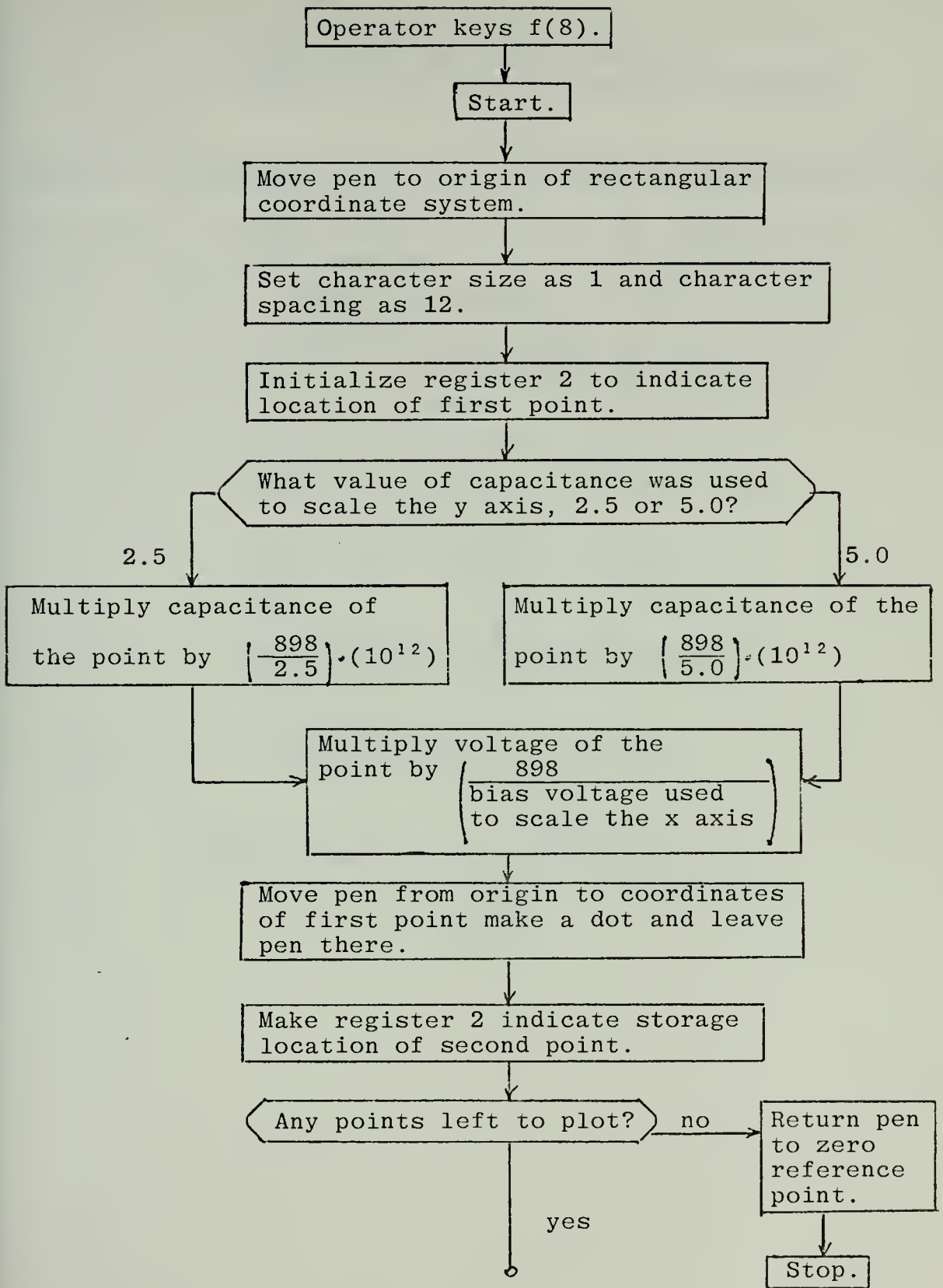


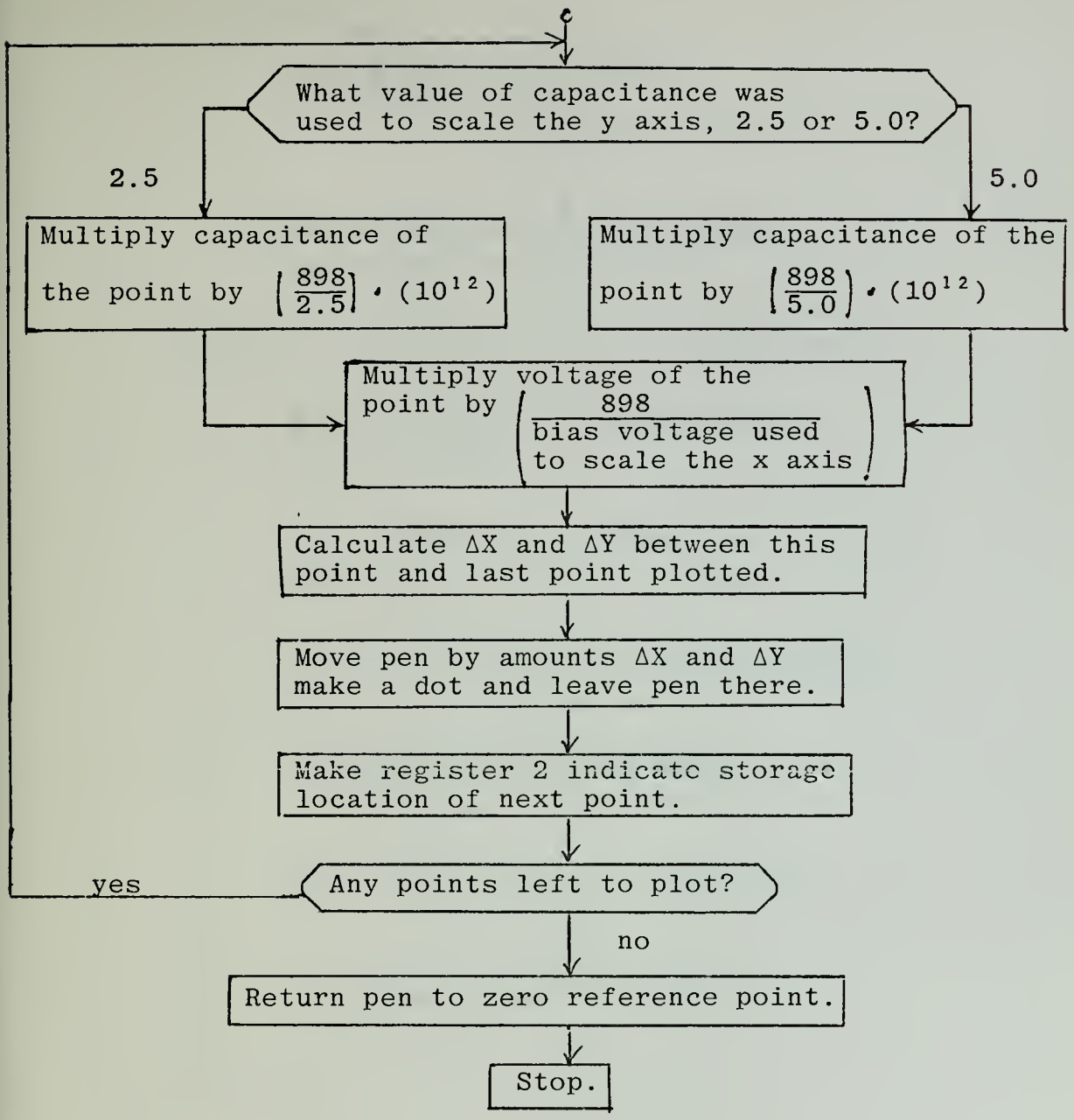

Operator keys f(6).
Start.
Designate register 2 as a pointer register. Initialize it to indicate register 30.
Designate register 3 as a pointer register. Recall register 4 and store in register 3. This makes register 3 indicate the first available register for bias voltage storage.
Designate register 5 to indicate the number of the bias voltage to be entered. Initialize it to 1.
Stop.
Operator enters bias voltage into display register and keys go.
Start.
Take bias voltage from display register and store in register indicated by register 3.
Add 1 to register 3
Recall y voltage indicated by register 2 and store in register 6.
Add 1 to register 2.
Recall x voltage indicated by register 2 and store in register 7.

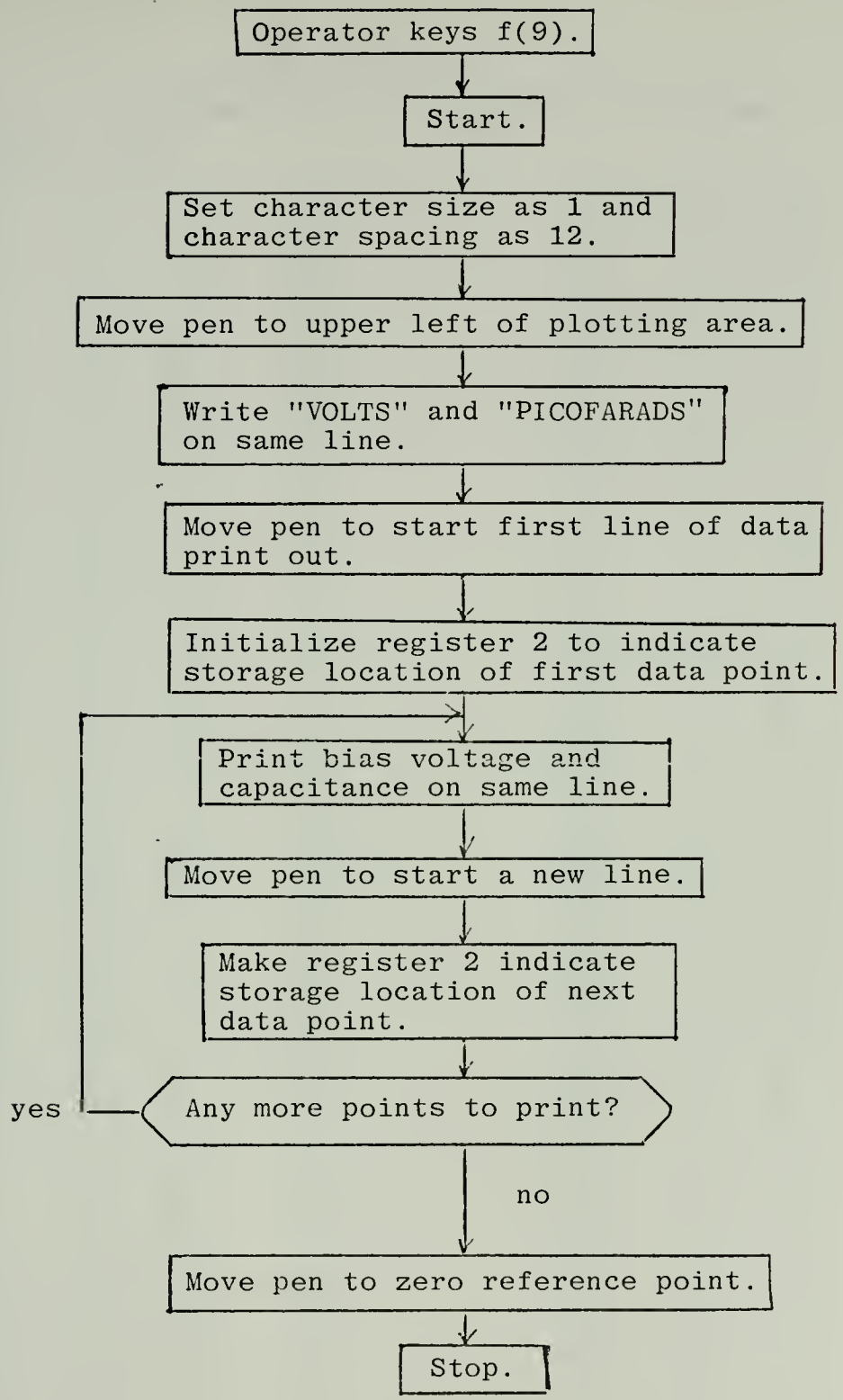

Add 1 to register 2.
Recall frequency indicated by register 2 and store in register 8.
Add 1 to register 2.
Evaluate C = $-\frac{(1-x)^2 + y^2}{200\ \pi f y}$ for data point just recalled.
Store result in register indicated by register 3.
Add 1 to register 3.
Add 1 to register 5.
Stop.


Operator keys f(7).
Start.
Move pen to negative end of x axis.
Set character size as 1 and character spacing as 12.
Designate register 2 as a pointer register. Initialize it to indicate storage location of first bias voltage.
Recall bias voltage indicated by register 2 and store it in register 7.
Add 2 to register 2.
Recall bias voltage indicated by register 2 and compare it to bias voltage in register 7.
yes
Is it larger than the voltage in register 7?
no
Add 2 to register 2.
Any bias voltages left to test?
yes
no
Using the bias voltage in register 7, scale the x axis.
Move pen to positive end of y axis.
Initialize register 2 to indicate storage location of first capacitance.


Recall capacitance indicated by register 2 and store it in register 7.
Add 2 to register 2.
Recall capacitance indicated by register 2 and compare it to capacitance in register 7.
Is it larger than the capacitance in register 7?
yes
no
Add 2 to register 2.
Any capacitances left to test?
yes
no
Is the capacitance in register 7 less than 2 picofarads?
yes
no
Use 2.5 picofarads as maximum y axis value
Use 5.0 picofarads as maximum y axis value.
Scale the y axis.
Return pen to zero reference point
Stop.


Operator keys f(8).
Start.
Move pen to origin of rectangular coordinate system.
Set character size as 1 and character spacing as 12.
Initialize register 2 to indicate location of first point.
What value of capacitance was used to scale the y axis, 2.5 or 5.0?
2.5
5.0
Multiply capacitance of the point by (898/2.5)·(10^12)
Multiply capacitance of the point by (898/5.0)·(10^12)
Multiply voltage of the point by (898 / bias voltage used to scale the x axis)
Move pen from origin to coordinates of first point make a dot and leave pen there.
Make register 2 indicate storage location of second point.
Any points left to plot?
no
yes
Return pen to zero reference point.
Stop.


c
What value of capacitance was used to scale the y axis, 2.5 or 5.0?
2.5
5.0
Multiply capacitance of the point by $\left(\frac{898}{2.5}\right) \cdot (10^{12})$
Multiply capacitance of the point by $\left(\frac{898}{5.0}\right) \cdot (10^{12})$
Multiply voltage of the point by $\left(\frac{898}{\text{bias voltage used to scale the x axis}}\right)$
Calculate ΔX and ΔY between this point and last point plotted.
Move pen by amounts ΔX and ΔY make a dot and leave pen there.
Make register 2 indicate storage location of next point.
Any points left to plot?
yes
no
Return pen to zero reference point.
Stop.


Operator keys f(9).
Start.
Set character size as 1 and character spacing as 12.
Move pen to upper left of plotting area.
Write "VOLTS" and "PICOFARADS" on same line.
Move pen to start first line of data print out.
Initialize register 2 to indicate storage location of first data point.
Print bias voltage and capacitance on same line.
Move pen to start a new line.
Make register 2 indicate storage location of next data point.
Any more points to print?
yes
no
Move pen to zero reference point.
Stop.

APPENDIX E: S_{11}/S_{22}-PRINTING PROGRAM

Verify = 3177

```
0000  09 00   *  M          0040  09 15   *  RI
0001  00 01   E 1           0041  09 00   *  M
0002  06 10   ST10          0042  10 02   f 2
0003  00 01   E 1           0043  07 01   RE 1
0004  00 06   E 6           0044  08 12   *  x²
0005  06 00   ST 0          0045  06 14   ST14
0006  07 10   RE10          0046  07 02   RE 2
0007  15 11   D11           0047  08 12   *  x²
0008  06 00   ST 0          0048  02 14   +14
0009  10 01   f 1           0049  08 13   *  √x
0010  10 02   f 2           0050  06 04   ST 4
0011  10 00   f 0           0051  09 15   *  RI
0012  10 03   f 3           0052  09 00   *  M
0013  10 04   f 4           0053  10 03   f 3
0014  10 07   f 7           0054  07 01   RE 1
0015  10 08   f 8           0055  08 05   *  J+
0016  10 10   f10           0056  08 00   *  S
0017  10 11   f11           0057  00 02   E 2
0018  09 03   *  SP         0058  07 02   RE 2
0019  09 00   *  M          0059  06 14   ST14
0020  10 01   f 1           0060  08 05   *  J+
0021  15 13   D13           0061  08 00   *  S
0022  07 01   RE 1          0062  00 03   E 3
0023  06 01   ST 1          0063  07 04   RE 4
0024  15 11   D11           0064  05 14   ÷14
0025  07 00   RE 0          0065  09 06   *  S'
0026  05 01   ÷ 1           0066  06 05   ST 5
0027  15 13   D13           0067  09 15   *  RI
0028  07 02   RE 2          0068  09 00   *  M
0029  06 02   ST 2          0069  00 02   E 2
0030  15 11   D11           0070  07 02   RE 2
0031  07 00   RE 0          0071  06 14   ST14
0032  05 02   ÷ 2           0072  08 05   *  J+
0033  15 13   D13           0073  08 00   *  S
0034  07 03   RE 3          0074  00 04   E 4
0035  15 13   D13           0075  00 01   E 1
0036  07 03   RE 3          0076  00 08   E 8
0037  06 03   ST 3          0077  00 00   E 0
0038  00 02   E 2           0078  06 05   ST 5
0039  02 03   + 3           0079  07 04   RE 4
```

```
0080  05 14   ÷14
0081  09 06   *    S'
0082  03 05   -5
0083  09 15   *    RT
0084  09 00   *    M
0085  00 03   E3
0086  00 12   E12
0087  06 14   ST14
0088  00 03   E3
0089  00 06   E6
0090  00 00   E0
0091  06 05   ST5
0092  07 04   RE4
0093  05 14   ÷14
0094  09 06   *    S'
0095  03 05   -5
0096  09 15   *    RT
0097  09 00   *    M
0098  00 04   E4
0099  00 12   E12
0100  06 14   ST14
0101  00 01   E1
0102  00 08   E8
0103  00 00   E0
0104  06 05   ST5
0105  07 04   RE4
0106  05 14   ÷14
0107  09 06   *    S'
0108  02 05   +5
0109  10 05   f5
0110  09 15   *    RT
0111  09 00   *    M
0112  10 04   f4
0113  10 06   f6
0114  07 03   RE3
0115  10 05   f5
0116  10 06   f6
0117  07 06   RE6
0118  10 05   f5
0119  10 06   f6
0120  07 01   RE1
0121  10 05   f5
0122  10 06   f6
0123  07 02   RE2
0124  10 05   f5
0125  10 06   f6
0126  07 04   RE4
0127  10 05   f5
0128  10 06   f6
0129  07 05   RE5
0130  10 05   f5
0131  09 15   *    RT
0132  09 00   *    M
0133  10 05   f5
0134  15 11   D11
0135  06 00   ST0
0136  09 15   *    RT
0137  09 00   *    M
0138  10 06   f6
0139  00 01   E1
0140  02 00   +0
0141  09 15   *    RT
0142  09 00   *    M
0143  10 07   f7
0144  07 01   RE1
0145  06 06   ST6
0146  00 01   E1
0147  02 01   +1
0148  10 02   f2
0149  10 03   f3
0150  07 04   RE4
0151  06 07   ST7
0152  07 05   RE5
0153  06 08   ST8
0154  00 02   E2
0155  04 06   ×6
0156  03 01   -1
0157  07 02   RE2
0158  00 12   E12
0159  06 02   ST2
```

```
0160  10 02   f 2
0161  10 03   f 3
0162  07 04   RE 4
0163  05 07   ÷ 7
0164  06 04   ST 4
0165  07 05   RE 5
0166  03 08   − 8
0167  06 05   ST 5
0168  09 15   *  RT
0169  09 00   *  M
0170  10 08   f 8
0171  07 05   RE 5
0172  08 07   *  CS
0173  06 01   ST 1
0174  07 04   RE 4
0175  04 01   × 1
0176  07 05   RE 5
0177  08 05   *  J+
0178  10 09   f 9
0179  09 15   *  RT
0180  08 06   *  SN
0181  06 02   ST 2
0182  07 04   RE 4
0183  04 02   × 2
0184  09 15   *  RT
0185  09 00   *  M
0186  10 09   f 9
0187  00 12   E 12
0188  08 06   *  SN
0189  06 02   ST 2
0190  00 01   E 1
0191  00 12   E 12
0192  04 02   × 2
0193  07 04   RE 4
0194  04 02   × 2
0195  09 15   *  RT
0196  09 00   *  M
0197  10 10   f 10
0198  10 06   f 6
0199  07 01   RE 1
```

```
0200  10 05   f 5
0201  10 06   f 6
0202  07 02   RE 2
0203  10 05   f 5
0204  10 06   f 6
0205  07 04   RE 4
0206  10 05   f 5
0207  10 06   f 6
0208  07 05   RE 5
0209  10 05   f 5
0210  09 15   *  RT
0211  09 00   *  M
0212  10 11   f 11
0213  07 00   RE 0
0214  06 01   ST 1
0215  00 01   E 1
0216  00 06   E 6
0217  06 00   ST 0
0218  09 00   *  M
0219  00 05   E 5
0220  10 06   f 6
0221  10 12   f 12
0222  07 01   RE 1
0223  09 02   *  α
0224  08 04   *  Jo
0225  08 00   *  S
0226  00 05   E 5
0227  08 02   *  W
0228  06 15   ST 15
0229  08 02   *  W
0230  06 15   ST 15
0231  08 02   *  W
0232  06 15   ST 15
0233  07 10   RE 10
0234  09 15   *  RT
0235  09 00   *  M
0236  10 12   f 12
0237  15 11   D 11
0238  07 00   RE 0
0239  08 02   *  W
```

```
0240   06 04     ST 4
0241   09 15     *    XT
0242   09 00     *    M
0243   10 00     f 0
0244   07 04     RE 4
0245   06 06     ST 6
0246   06 07     ST 7
0247   00 01     E 1
0248   00 12     E 12
0249   04 07     × 7
0250   00 01     E 1
0251   02 06     + 6
0252   00 01     E 1
0253   02 07     + 7
0254   05 06     ÷ 6
0255   09 15     *    RT
0256   09 03     *    SP
0257   09 14     *    EP
```

APPENDIX F: SMITH CHART-PLOTTING AND LISTING PROGRAM

```
Verify =.6980
0000  09 00   *    .M
0001  00 01   E1
0002  00 00   E0
0003  06 00   ST0
0004  00 01   E1
0005  06 01   ST1
0006  09 02   *    α
0007  05 08   ÷8
0008  02 02   +2
0009  00 01   E1
0010  00 02   E2
0011  06 01   ST1
0012  09 02   *    α
0013  05 10   ÷10
0014  02 02   +2
0015  00 05   E5
0016  00 04   E4
0017  00 07   E7
0018  06 00   ST0
0019  00 05   E5
0020  00 06   E6
0021  00 03   E3
0022  06 01   ST1
0023  00 04   E4
0024  00 04   E4
0025  00 09   E9
0026  06 03   ST3
0027  09 02   *    α
0028  05 11   ÷11
0029  05 03   ÷3
0030  02 02   +2
0031  00 00   E0
0032  06 00   ST0
0033  07 03   RE3
0034  06 01   ST1
0035  09 02   *    α
0036  05 03   ÷3
0037  02 02   +2
0038  00 01   E1
0039  00 00   E0
0040  06 07   ST7
0041  00 03   E3
0042  00 07   E7
0043  00 00   E0
0044  06 08   ST8
0045  00 00   E0
0046  06 04   ST4
0047  06 05   ST5
0048  00 04   E4
0049  00 04   E4
0050  00 09   E9
0051  06 06   ST6
0052  00 00   E0
0053  06 10   ST10
0054  06 11   ST11
0055  09 00   *    M
0056  00 04   E4
0057  07 07   RE7
0058  08 06   *    SN
0059  06 00   ST0
0060  07 03   RE3
0061  04 00   ×0
0062  06 12   ST12
0063  07 07   RE7
0064  08 07   *    CS
0065  06 01   ST1
0066  07 03   RE3
0067  04 01   ×1
0068  06 13   ST13
0069  07 05   RE5
0070  03 00   -0
0071  07 06   RE6
0072  03 01   -1
0073  07 12   RE12
0074  06 05   ST5
0075  07 13   RC13
0076  06 06   ST6
0077  07 10   RE10
0078  02 00   +0
0079  07 11   RE11
```

```
0080  02 01   +1
0081  09 02   *   α
0082  05 02   ÷2
0083  02 02   +2
0084  07 00   RE0
0085  06 14   ST14
0086  09 12   *   I
0087  03 14   -14
0088  06 10   ST10
0089  07 01   RE1
0090  06 14   ST14
0091  09 12   *   I
0092  03 14   -14
0093  06 11   ST11
0094  00 01   E1
0095  00 00   E0
0096  02 07   +7
0097  06 14   ST14
0098  07 08   RE8
0099  03 14   -14
0100  08 05   *   J+
0101  08 00   *   S
0102  00 04   E4
0103  00 01   E1
0104  02 04   +4
0105  00 02   E2
0106  06 14   ST14
0107  07 04   RE4
0108  03 14   -14
0109  09 04   *   J-
0110  08 00   *   S
0111  00 05   E5
0112  00 03   E3
0113  06 14   ST14
0114  07 04   RE4
0115  03 14   -14
0116  09 04   *   J-
0117  08 00   *   S
0118  00 06   E6
0119  00 04   E4
0120  06 14   ST14
0121  07 04   RE4
0122  03 14   -14
0123  09 04   *   J-
0124  08 00   *   S
0125  00 07   E7
0126  00 02   E2
0127  00 02   E2
0128  00 04   E4
0129  06 03   ST3
0130  00 01   E1
0131  00 00   E0
0132  06 07   ST7
0133  00 00   E0
0134  06 05   ST5
0135  00 02   E2
0136  00 02   E2
0137  00 04   E4
0138  06 06   ST6
0139  08 00   *   S
0140  00 04   E4
0141  09 00   *   M
0142  00 05   E5
0143  00 04   E4
0144  00 04   E4
0145  00 09   E9
0146  06 03   ST3
0147  00 01   E1
0148  00 00   E0
0149  00 00   E0
0150  06 07   ST7
0151  00 01   E1
0152  00 09   E9
0153  00 00   E0
0154  06 08   ST8
0155  00 04   E4
0156  00 04   E4
0157  00 09   E9
0158  06 05   ST5
0159  00 00   E0
```

0160	06	06	ST6
0161	08	00	* S
0162	00	04	E4
0163	09	00	* M
0164	00	06	E6
0165	00	08	E8
0166	00	09	E9
0167	00	08	E8
0168	06	00	ST0
0169	00	00	E0
0170	06	01	ST1
0171	09	02	* α
0172	05	03	÷3
0173	02	02	+2
0174	00	04	E4
0175	00	04	E4
0176	00	09	E9
0177	06	03	ST3
0178	00	01	E1
0179	00	09	E9
0180	00	00	E0
0181	06	07	ST7
0182	00	02	E2
0183	00	08	E8
0184	00	00	E0
0185	06	08	ST8
0186	00	00	E0
0187	06	05	ST5
0188	00	12	E12
0189	00	04	E4
0190	00	04	E4
0191	00	09	E9
0192	06	06	ST6
0193	08	00	* S
0194	00	04	E4
0195	09	00	* M
0196	00	07	E7
0197	00	00	E0
0198	06	00	ST0
0199	00	12	E12

0200	00	08	E8
0201	00	09	E9
0202	00	08	E8
0203	06	01	ST1
0204	09	02	* α
0205	05	02	÷2
0206	02	02	+2
0207	00	05	E5
0208	00	00	E0
0209	00	05	E5
0210	06	00	ST0
0211	00	02	E2
0212	00	05	E5
0213	00	00	E0
0214	06	01	ST1
0215	09	02	* α
0216	05	03	÷3
0217	02	02	+2
0218	00	01	E1
0219	06	01	ST1
0220	09	02	* α
0221	05	08	÷8
0222	02	02	+2
0223	00	00	E0
0224	06	00	ST0
0225	00	01	E1
0226	00	02	E2
0227	06	01	ST1
0228	09	02	* α
0229	05	10	÷10
0230	01	04	T4
0231	01	15	T15
0232	00	05	E5
0233	02	05	+5
0234	02	13	+13
0235	01	12	T12
0236	02	06	+6
0237	02	12	+12
0238	02	05	+5
0239	05	03	÷3

```
0240   01 09     T 9
0241   01 13     T13
0242   05 03     ÷3
0243   01 12     T12
0244   02 13     +13
0245   01 15     T15
0246   01 04     T 4
0247   02 07     + 7
0248   02 07     + 7
0249   01 12     T12
0250   02 06     + 6
0251   02 12     +12
0252   02 05     + 5
0253   05 03     ÷3
0254   02 12     +12
0255   01 09     T 9
0256   01 09     T 9
0257   01 13     T13
0258   02 13     +13
0259   01 04     T 4
0260   02 06     + 6
0261   01 12     T12
0262   02 07     + 7
0263   02 05     + 5
0264   01 01     T 1
0265   05 11     ÷11
0266   02 02     + 2
0267   09 03     *    P
```

```
0263   09  00      *     M
0269   00  02      E 2
0270   06  15      ST15
0271   00  02      E 2
0272   00  10      E10
0273   00  01      E 1
0274   06  14      ST14
0275   00  02      E 2
0276   00  00      E 0
0277   05  15      ÷15
0278   09  11      *     W
0279   09  01      *     ST
0280   01  09      T 9
0281   05  14      ÷14
0282   09  01      *     ST
0283   01  08      T 8
0284   00  03      E 3
0285   00  00      E 0
0286   06  02      ST 2
0287   09  03      *     SP
```

```
0288  09 00   *  M
0289  10 01   f 1
0290  15 13   D13
0291  07 02   RE 2
0292  06 14   ST14
0293  08 01   *  RE
0294  01 08   T 8
0295  05 14   ÷14
0296  15 11   D11
0297  06 02   ST 2
0298  00 01   E 1
0299  02 02   + 2
0300  15 13   D13
0301  07 01   RE 1
0302  06 14   ST14
0303  08 01   *  RE
0304  01 08   T 8
0305  05 14   ÷14
0306  15 11   D11
0307  06 02   ST 2
0308  00 01   E 1
0309  02 02   + 2
0310  15 13   D13
0311  07 03   RE 3
0312  15 13   D13
0313  07 03   RE 3
0314  06 14   ST14
0315  09 02   *  α
0316  11 01   F 1
0317  09 12   *  I
0318  06 15   ST15
0319  09 02   *  α
0320  10 01   f 1
0321  03 14   -14
0322  00 02   E 2
0323  02 14   +14
0324  09 00   *  M
0325  08 06   *  SN
0326  00 01   E 1
0327  03 14   -14
0328  00 01   E 1
0329  00 00   E 0
0330  04 15   ×15
0331  07 14   RE14
0332  08 04   *  Jo
0333  08 00   *  S
0334  08 06   *  SN
0335  07 15   RE15
0336  15 11   D11
0337  06 02   ST 2
0338  00 01   E 1
0339  02 02   + 2
0340  06 04   ST 4
0341  09 15   *  RT
```

```
0342  09 00   *    M
0343  10 02   f2
0344  00 00   E0
0345  06 00   ST0
0346  00 01   E1
0347  06 01   ST1
0348  09 02   *    α
0349  05 08   ÷8
0350  02 02   +2
0351  00 01   E1
0352  00 02   E2
0353  06 01   ST1
0354  09 02   *    α
0355  05 10   ÷10
0356  02 02   +2
0357  00 05   E5
0358  00 04   E4
0359  00 07   E7
0360  06 00   ST0
0361  00 05   E5
0362  00 06   E6
0363  00 03   E3
0364  06 01   ST1
0365  00 03   E3
0366  00 00   E0
0367  06 02   ST2
0368  00 04   E4
0369  00 04   E4
0370  00 09   E9
0371  06 03   ST3
0372  09 02   *    α
0373  05 11   ÷11
0374  05 03   ÷3
0375  02 02   +2
0376  01 00   T0
0377  01 01   T1
0378  01 10   T10
0379  01 11   T11
0380  11 01   F1
0381  08 05   *    J+
0382  11 02   F2
0383  08 05   *    J+
0384  11 03   F3
0385  08 03   *    G∞
0386  07 05   RE5
0387  06 00   ST0
0388  07 06   RE6
0389  06 01   ST1
0390  00 02   E2
0391  02 02   +2
0392  09 02   *    α
0393  05 03   ÷3
0394  01 06   T6
0395  02 02   +2
0396  10 10   f10
0397  07 04   RE4
0398  06 14   ST14
0399  07 02   RE2
0400  03 14   −14
0401  08 04   *    J∞
0402  08 00   *    S
0403  00 03   E3
0404  09 02   *    α
0405  05 11   ÷11
0406  02 02   +2
0407  09 03   *    SP
0408  09 00   *    M
0409  00 03   E3
0410  07 10   RE10
0411  02 00   +0
0412  07 11   RE11
0413  02 01   +1
0414  07 00   RE0
0415  00 12   E12
0416  06 00   ST0
0417  07 01   RE1
0418  00 12   E12
0419  06 01   ST1
0420  11 01   F1
0421  08 05   *    J+
```

```
0422  11 02   F 2
0423  08 05   * Jx
0424  11 03   F 3
0425  08 03   * ∞
0426  07 05   RE 5
0427  02 00   + 0
0428  07 06   RE 6
0429  02 01   + 1
0430  09 02   *  α
0431  05 03   ÷ 3
0432  01 06   T 6
0433  02 02   + 2
0434  10 10   f 10
0435  07 05   RE 5
0436  06 00   ST 0
0437  07 06   RE 6
0438  06 01   ST 1
0439  00 02   E 2
0440  02 02   + 2
0441  07 04   RE 4
0442  06 14   ST 14
0443  07 02   RE 2
0444  03 14   − 14
0445  08 04   * Jo
0446  08 00   * S
0447  00 03   E 3
0448  09 02   *  α
0449  05 11   ÷ 11
0450  02 02   + 2
0451  09 03   *  SP
0452  09 00   *  M
0453  10 10   f 10
0454  07 00   RE 0
0455  06 07   ST 7
0456  07 01   RE 1
0457  06 08   ST 8
0458  00 00   E 0
0459  06 00   ST 0
0460  00 01   E 1
0461  00 02   E 2
0462  00 12   E 12
0463  06 01   ST 1
0464  09 02   *  α
0465  05 03   ÷ 3
0466  02 02   + 2
0467  07 07   RE 7
0468  06 00   ST 0
0469  07 08   RE 8
0470  06 01   ST 1
0471  09 15   *  RT
```

```
0472  09 00   *  M
0473  10 03   f3
0474  09 02   *  α
0475  05 11   ÷11
0476  02 02   +2
0477  00 09   E9
0478  00 09   E9
0479  00 09   E9
0480  06 00   ST0
0481  00 09   E9
0482  00 09   E9
0483  00 09   E9
0484  06 01   ST1
0485  06 01   ST1
0486  09 02   *  α
0487  05 03   ÷3
0488  02 02   +2
0489  00 00   E0
0490  06 00   ST0
0491  00 01   E1
0492  06 01   ST1
0493  09 02   *  α
0494  05 08   ÷8
0495  02 02   +2
0496  00 00   E0
0497  06 00   ST0
0498  00 01   E1
0499  00 02   E2
0500  06 01   ST1
0501  09 02   *  α
0502  05 10   ÷10
0503  02 02   +2
0504  00 00   E0
0505  06 00   ST0
0506  00 04   E4
0507  00 00   E0
0508  06 01   ST1
0509  09 02   *  α
0510  05 03   ÷3
0511  02 02   +2
0512  00 03   E3
0513  00 02   E2
0514  06 02   ST2
0515  09 00   *  M
0516  08 07   *  CS
0517  15 11   D11
0518  07 02   RC2
0519  15 02   D2
0520  01 01   T1
0521  00 03   E3
0522  02 02   +2
0523  00 02   E2
0524  00 00   E0
0525  00 12   E12
0526  06 00   ST0
0527  00 01   E1
0528  00 09   E9
0529  00 02   E2
0530  00 12   E12
0531  06 01   ST1
0532  09 02   *  α
0533  05 03   ÷3
0534  02 02   +2
0535  07 02   RE2
0536  06 00   ST0
0537  07 04   RE4
0538  09 02   *  α
0539  08 05   *  J+
0540  08 00   *  S
0541  08 07   *  CS
0542  07 04   RE4
0543  06 02   ST2
0544  09 02   *  α
0545  05 11   ÷11
0546  02 02   +2
0547  09 15   *  RT
```

0548	09	00	* M	0588	00	00	E 0
0549	10	04	f 4	0589	06	02	ST 2
0550	09	02	* α	0590	09	00	* M
0551	05	11	÷11	0591	09	07	* C'
0552	02	02	+2	0592	15	11	D11
0553	00	05	E 5	0593	07	02	RE 2
0554	00	01	E 1	0594	06	05	ST 5
0555	00	00	E 0	0595	00	01	E 1
0556	06	00	ST 0	0596	02	02	+2
0557	00	09	E 9	0597	15	11	D11
0558	00	09	E 9	0598	07	02	RE 2
0559	00	09	E 9	0599	06	06	ST 6
0560	06	01	ST 1	0600	07	05	RE 5
0561	09	02	* α	0601	08	12	* x^2
0562	05	03	÷3	0602	06	14	ST 14
0563	02	02	+2	0603	07	06	RE 6
0564	00	00	E 0	0604	00	12	E 12
0565	06	00	ST 0	0605	06	15	ST 15
0566	00	04	E 4	0606	00	01	E 1
0567	00	00	E 0	0607	02	15	+15
0568	06	01	ST 1	0608	08	12	* x^2
0569	09	02	* α	0609	02	14	+14
0570	05	03	÷3	0610	06	07	ST 7
0571	02	02	+2	0611	07	05	RE 5
0572	00	00	E 0	0612	08	12	* x^2
0573	06	00	ST 0	0613	00	12	E 12
0574	00	01	E 1	0614	06	14	ST 14
0575	06	01	ST 1	0615	07	06	RE 6
0576	09	02	* α	0616	08	12	* x^2
0577	05	08	÷8	0617	00	12	E 12
0578	02	02	+2	0618	02	14	+14
0579	00	00	E 0	0619	00	01	E 1
0580	06	00	ST 0	0620	02	14	+14
0581	00	01	E 1	0621	07	07	RE 7
0582	00	02	E 2	0622	05	14	÷14
0583	06	01	ST 1	0623	06	08	ST 8
0584	09	02	* α	0624	07	05	RE 5
0585	05	10	÷10	0625	06	14	ST 14
0586	02	02	+2	0626	00	02	E 2
0587	00	03	E 3	0627	04	14	×14

0628	07	07	RE 7
0629	05	14	÷14
0630	06	09	ST 9
0631	07	08	RE 8
0632	15	02	D 2
0633	03	03	− 3
0634	00	00	E 0
0635	06	00	ST 0
0636	00	01	E 1
0637	00	02	E 2
0638	06	01	ST 1
0639	09	02	* α
0640	05	03	÷ 3
0641	02	02	+ 2
0642	07	09	RE 9
0643	15	02	D 2
0644	03	03	− 3
0645	00	02	E 2
0646	00	00	E 0
0647	00	12	E 12
0648	06	00	ST 0
0649	00	02	E 2
0650	00	00	E 0
0651	00	04	E 4
0652	00	12	E 12
0653	06	01	ST 1
0654	09	02	* α
0655	05	03	÷ 3
0656	02	02	+ 2
0657	00	02	E 2
0658	02	02	+ 2
0659	07	04	RE 4
0660	06	14	ST 14
0661	07	02	RE 2
0662	03	14	− 14
0663	08	04	* J_0
0664	08	00	* S
0665	09	07	* C'
0666	07	04	RE 4
0667	06	02	ST 2
0668	09	02	* α
0669	05	11	÷ 11
0670	02	02	+ 2
0671	09	15	* RT
0672	09	00	* M
0673	11	01	F 1
0674	15	11	D 11
0675	07	02	RE 2
0676	08	12	* x^2
0677	06	14	ST 14
0678	00	01	E 1
0679	02	02	+ 2
0680	15	11	D 11
0681	07	02	RE 2
0682	08	12	* x^2
0683	02	14	+ 14
0684	08	13	* $\sqrt{x}$
0685	06	15	ST 15
0686	00	01	E 1
0687	03	15	− 15
0688	09	15	* RT
0689	09	00	* M
0690	11	02	F 2
0691	00	01	E 1
0692	03	02	− 2
0693	15	11	D 11
0694	07	02	RE 2
0695	06	05	ST 5
0696	08	01	* RE
0697	01	08	T 8
0698	04	05	× 5
0699	00	01	E 1
0700	02	02	+ 2
0701	15	11	D 11
0702	07	02	RE 2
0703	06	06	ST 6
0704	08	01	* RE
0705	01	08	T 8
0706	04	06	× 6
0707	08	01	* RE

```
0708   01 09    T9
0709   04 05    ×5
0710   08 01    *  RE
0711   01 09    T9
0712   04 06    ×6
0713   00 02    E2
0714   00 10    E10
0715   00 01    E1
0716   05 05    ÷5
0717   00 02    E2
0718   00 10    E10
0719   00 01    E1
0720   05 06    ÷6
0721   07 03    RE3
0722   04 05    ×5
0723   07 03    RE3
0724   04 06    ×6
0725   00 01    E1
0726   09 15    *    RT
0727   09 00    *    M
0728   11 03    F3
0729   00 01    E1
0730   03 02    -2
0731   15 11    D11
0732   07 02    RE2
0733   06 15    ST15
0734   07 14    RE14
0735   05 15    ÷15
0736   06 05    ST5
0737   00 01    E1
0738   02 02    +2
0739   15 11    D11
0740   07 02    RE2
0741   06 15    ST15
0742   07 14    RE14
0743   05 15    ÷15
0744   06 06    ST6
0745   07 03    RE3
0746   04 05    ×5
0747   07 03    RE3
0748   04 06    ×6
0749   09 15    *    RT
0750   09 14    *    EP
```

APPENDIX G

S_{12}/S_{21} POLAR COORDINATES-PLOTTING AND LISTING PROGRAM

Verify = 7738

```
0000  09 00   * M          0040  00 01   E 1
0001  00 01   E 1           0041  00 00   E 0
0002  09 01   * SI          0042  06 07   ST 7
0003  01 04   T 4           0043  00 03   E 3
0004  00 00   E 0           0044  00 07   E 7
0005  06 00   ST 0          0045  00 00   E 0
0006  00 01   E 1           0046  06 08   ST 8
0007  06 01   ST 1          0047  00 00   E 0
0008  09 02   * α           0048  06 04   ST 4
0009  05 08   ÷ 8           0049  06 05   ST 5
0010  02 02   + 2           0050  00 04   E 4
0011  00 01   E 1           0051  00 04   E 4
0012  00 02   E 2           0052  00 09   E 9
0013  06 01   ST 1          0053  06 06   ST 6
0014  09 02   * α           0054  00 00   E 0
0015  05 10   ÷ 10          0055  06 10   ST 10
0016  02 02   + 2           0056  06 11   ST 11
0017  00 05   E 5           0057  09 00   * M
0018  00 04   E 4           0058  00 04   E 4
0019  00 07   E 7           0059  07 07   RE 7
0020  06 00   ST 0          0060  08 06   * SM
0021  00 05   E 5           0061  06 00   ST 0
0022  00 06   E 6           0062  07 03   RE 3
0023  00 03   E 3           0063  04 00   × 0
0024  06 01   ST 1          0064  06 12   ST 12
0025  00 04   E 4           0065  07 07   RE 7
0026  00 04   E 4           0066  08 07   * CS
0027  00 09   E 9           0067  06 01   ST 1
0028  06 03   ST 3          0068  07 03   RE 3
0029  09 02   * α           0069  04 01   × 1
0030  05 11   ÷ 11          0070  06 13   ST 13
0031  05 03   ÷ 3           0071  07 05   RE 5
0032  02 02   + 2           0072  03 00   - 0
0033  00 00   E 0           0073  07 06   RE 6
0034  06 00   ST 0          0074  03 01   - 1
0035  07 03   RE 3          0075  07 12   RE 12
0036  06 01   ST 1          0076  06 05   ST 5
0037  09 02   * α           0077  07 13   RE 13
0038  05 03   ÷ 3           0078  06 06   ST 6
0039  02 02   + 2           0079  07 10   RE 10
```

0080	02	00	+0
0081	07	11	↓11
0082	02	01	+1
0083	09	02	* α
0084	05	02	÷2
0085	02	02	+2
0086	07	00	↓0
0087	06	14	ST14
0088	09	12	* I
0089	03	14	−14
0090	06	10	ST10
0091	07	01	↓1
0092	06	14	ST14
0093	09	12	* I
0094	03	14	−14
0095	06	11	ST11
0096	00	01	E1
0097	00	00	E0
0098	02	07	+7
0099	06	14	ST14
0100	07	08	↓8
0101	03	14	−14
0102	08	05	* J.
0103	08	00	* S
0104	00	04	E4
0105	00	00	E0
0106	06	00	ST0
0107	00	09	E9
0108	00	00	E0
0109	00	12	E12
0110	06	01	ST1
0111	09	02	* α
0112	05	03	÷3
0113	02	02	+2
0114	00	01	E1
0115	02	04	+4
0116	00	02	E2
0117	06	14	ST14
0118	07	04	↓4
0119	03	14	−14
0120	09	04	* J.
0121	08	00	* S
0122	00	05	E5
0123	00	03	E3
0124	06	14	ST14
0125	07	04	↓4
0126	03	14	−14
0127	09	04	* J.
0128	08	00	* S
0129	00	06	E6
0130	00	04	E4
0131	06	14	ST14
0132	07	04	↓4
0133	03	14	−14
0134	09	04	* J.
0135	08	00	* S
0136	00	07	E7
0137	00	05	E5
0138	06	14	ST14
0139	07	04	↓4
0140	03	14	−14
0141	09	04	* J.
0142	08	00	* S
0143	00	08	E8
0144	00	03	E3
0145	00	05	E5
0146	00	09	E9
0147	06	03	ST3
0148	00	01	E1
0149	00	00	E0
0150	06	07	ST7
0151	00	00	E0
0152	06	05	ST5
0153	00	03	E3
0154	00	05	E5
0155	00	09	E9
0156	06	06	ST6
0157	08	00	* S
0158	00	04	E4
0159	09	00	* M

0160	00	05	E5	0200	06	07	ST7
0161	00	02	E2	0201	00	00	E0
0162	00	06	E6	0202	06	05	ST5
0163	00	09	E9	0203	00	09	E9
0164	06	03	ST3	0204	00	00	E0
0165	00	01	E1	0205	06	06	ST6
0166	00	00	E0	0206	08	00	* S
0167	06	07	ST7	0207	00	04	E4
0168	00	00	E0	0208	09	00	* M
0169	06	05	ST5	0209	00	08	E8
0170	00	02	E2	0210	00	00	E0
0171	00	06	E6	0211	06	00	ST0
0172	00	09	E9	0212	00	04	E4
0173	06	06	ST6	0213	00	04	E4
0174	08	00	* S	0214	00	09	E9
0175	00	04	E4	0215	06	01	ST1
0176	09	00	* M	0216	09	02	* α
0177	00	06	E6	0217	05	03	÷3
0178	00	01	E1	0218	02	02	+2
0179	00	08	E8	0219	00	08	E8
0180	00	00	E0	0220	00	09	E9
0181	06	03	ST3	0221	00	08	E8
0182	00	01	E1	0222	00	12	E12
0183	00	00	E0	0223	06	01	ST1
0184	06	07	ST7	0224	09	02	* α
0185	00	00	E0	0225	05	02	÷2
0186	06	05	ST5	0226	02	02	+2
0187	00	01	E1	0227	00	04	E4
0188	00	08	E8	0228	00	04	E4
0189	00	00	E0	0229	00	09	E9
0190	06	06	ST6	0230	06	00	ST0
0191	08	00	* S	0231	06	01	ST1
0192	00	04	E4	0232	09	02	* α
0193	09	00	* M	0233	05	03	÷3
0194	00	07	E7	0234	02	02	+2
0195	00	09	E9	0235	00	08	E8
0196	00	00	E0	0236	00	09	E9
0197	06	03	ST3	0237	00	08	E8
0198	00	01	E1	0238	00	12	E12
0199	00	00	E0	0239	06	00	ST0

0240	00	00	E0	0280	06	00	ST0
0241	06	01	ST1	0281	00	04	E4
0242	09	02	* α	0282	00	04	E4
0243	05	02	÷2	0283	00	08	E8
0244	02	02	+2	0284	00	12	E12
0245	00	06	E6	0285	06	01	ST1
0246	00	01	E1	0286	09	02	* α
0247	06	00	ST0	0287	05	02	÷2
0248	00	02	E2	0288	02	02	+2
0249	00	02	E2	0289	00	01	E1
0250	00	04	E4	0290	00	06	E6
0251	06	01	ST1	0291	00	04	E4
0252	09	02	* α	0292	06	00	ST0
0253	05	03	÷3	0293	00	01	E1
0254	02	02	+2	0294	00	06	E6
0255	00	07	E7	0295	00	04	E4
0256	00	07	E7	0296	00	12	E12
0257	00	06	E6	0297	06	01	ST1
0258	06	00	ST0	0298	09	02	* α
0259	00	04	E4	0299	05	03	÷3
0260	00	04	E4	0300	02	02	+2
0261	00	08	E8	0301	00	04	E4
0262	00	12	E12	0302	00	04	E4
0263	06	01	ST1	0303	00	08	E8
0264	09	02	* α	0304	06	00	ST0
0265	05	02	÷2	0305	00	07	E7
0266	02	02	+2	0306	00	07	E7
0267	00	00	E0	0307	00	06	E6
0268	06	00	ST0	0308	06	01	ST1
0269	00	04	E4	0309	09	02	* α
0270	00	04	E4	0310	05	02	÷2
0271	00	08	E8	0311	02	02	+2
0272	06	01	ST1	0312	00	04	E4
0273	09	02	* α	0313	00	04	E4
0274	05	03	÷3	0314	00	08	E8
0275	02	02	+2	0315	00	12	E12
0276	00	07	E7	0316	06	00	ST0
0277	00	07	E7	0317	00	00	E0
0278	00	06	E6	0318	06	01	ST1
0279	00	12	E12	0319	09	02	* α

0320	05	03	÷3
0321	02	02	+2
0322	00	04	E4
0323	00	04	E4
0324	00	08	E8
0325	06	00	ST0
0326	00	07	E7
0327	00	07	E7
0328	00	06	E6
0329	00	12	E12
0330	06	01	ST1
0331	09	02	* α
0332	05	02	÷2
0333	05	11	÷11
0334	02	02	+2
0335	08	01	* RE
0336	01	04	T4
0337	06	14	ST14
0338	00	02	E2
0339	00	00	E0
0340	05	14	÷14
0341	09	11	* W
0342	06	14	ST14
0343	00	05	E5
0344	00	04	E4
0345	00	07	E7
0346	06	00	ST0
0347	00	05	E5
0348	00	06	E6
0349	00	03	E3
0350	06	01	ST1
0351	09	02	* α
0352	05	03	÷3
0353	02	02	+2
0354	00	00	E0
0355	06	00	ST0
0356	00	04	E4
0357	00	06	E6
0358	00	01	E1
0359	06	01	ST1

0360	09	02	* α
0361	05	03	÷3
0362	02	02	+2
0363	07	14	RC14
0364	15	02	D2
0365	02	02	+2
0366	09	02	* α
0367	05	11	÷11
0368	02	02	+2
0369	09	03	* SP

```
0370   09 00      *    M
0371   00 02      E2
0372   09 01      *    SI
0373   01 08      T8
0374   00 03      E3
0375   00 00      E0
0376   06 02      SI2
0377   09 03      *    SP
```

```
0378  09 00   *  M
0379  10 01   f 1
0380  15 13   D13
0381  07 02   RE2
0382  06 14   ST14
0383  08 01   *  RE
0384  01 08   T 8
0385  05 14   ÷14
0386  15 11   D11
0387  06 02   ST 2
0388  00 01   E 1
0389  02 02   + 2
0390  15 13   D13
0391  07 01   RE 1
0392  06 14   ST14
0393  08 01   *  RE
0394  01 08   T 8
0395  05 14   ÷14
0396  15 11   D11
0397  06 02   ST 2
0398  00 01   E 1
0399  02 02   + 2
0400  15 13   D13
0401  07 03   RE 3
0402  15 13   D13
0403  07 03   RE 3
0404  06 14   ST14
0405  09 02   *  α
0406  11 01   F 1
0407  09 12   *  I
0408  06 15   ST15
0409  09 02   *  α
0410  10 01   f 1
0411  03 14   -14
0412  00 02   E 2
0413  02 14   +14
0414  09 00   *  M
0415  08 06   *  SN
0416  00 01   E 1
0417  03 14   -14
0418  00 01   E 1
0419  00 00   E 0
0420  04 15   ×15
0421  07 14   RE14
0422  08 04   *  Jo
0423  08 00   *  S
0424  06 06   *  SN
0425  07 15   RE15
0426  15 11   D11
0427  06 02   ST 2
0428  00 01   E 1
0429  02 02   + 2
0430  06 04   ST 4
0431  09 15   *  RI
```

```
0432  09 00   *  M
0433  10 02   f2
0434  00 00   E0
0435  06 00   ST0
0436  00 01   E1
0437  06 01   ST1
0438  09 02   *  α
0439  05 08   ÷8
0440  02 02   +2
0441  00 01   E1
0442  00 02   E2
0443  06 01   ST1
0444  09 02   *  α
0445  05 10   ÷10
0446  02 02   +2
0447  00 05   E5
0448  00 04   E4
0449  00 07   E7
0450  06 00   ST0
0451  00 05   E5
0452  00 06   E6
0453  00 03   E3
0454  06 01   ST1
0455  00 03   E3
0456  00 00   E0
0457  06 02   ST2
0458  00 04   E4
0459  00 04   E4
0460  00 09   E9
0461  06 03   ST3
0462  09 02   *  α
0463  05 11   ÷11
0464  05 03   ÷3
0465  02 02   +2
0466  01 00   T0
0467  01 01   T1
0468  01 10   T10
0469  01 11   T11
0470  15 11   D11
0471  07 02   RE2
0472  06 00   ST0
0473  07 03   RE3
0474  04 00   ×0
0475  00 01   E1
0476  02 02   +2
0477  15 11   D11
0478  07 02   RE2
0479  06 01   ST1
0480  07 03   RE3
0481  04 01   ×1
0482  00 02   E2
0483  02 02   +2
0484  09 02   *  α
0485  05 03   ÷3
0486  01 06   T6
0487  02 02   +2
0488  10 10   f10
0489  07 04   RE4
0490  06 14   ST14
0491  07 02   RE2
0492  03 14   −14
0493  08 04   *  Jo
0494  08 00   *  S
0495  00 03   E3
0496  09 02   *  α
0497  05 11   ÷11
0498  02 02   +2
0499  09 03   *  SP
0500  09 00   *  M
0501  00 03   E3
0502  07 10   RE10
0503  02 00   +0
0504  07 11   RE11
0505  02 01   +1
0506  07 00   RE0
0507  00 12   E12
0508  06 00   ST0
0509  07 01   RE1
0510  00 12   E12
0511  06 01   ST1
```

```
0512  15 11   D11
0513  07 02   RE2
0514  06 14   ST14
0515  07 03   RE3
0516  04 14   ×14
0517  02 00   +0
0518  00 01   E1
0519  02 02   +2
0520  15 11   D11
0521  07 02   RE2
0522  06 14   ST14
0523  07 03   RE3
0524  04 14   ×14
0525  02 01   +1
0526  00 01   E1
0527  03 02   −2
0528  09 02   *   α
0529  05 03   ÷3
0530  01 06   T6
0531  02 02   +2
0532  10 10   f10
0533  07 00   RE0
0534  06 14   ST14
0535  09 12   *   I
0536  03 14   −14
0537  06 10   ST10
0538  07 01   RE1
0539  06 14   ST14
0540  09 12   *   I
0541  03 14   −14
0542  06 11   ST11
0543  15 11   D11
0544  07 02   RE2
0545  06 14   ST14
0546  07 03   RE3
0547  04 14   ×14
0548  06 00   ST0
0549  00 01   E1
0550  02 02   +2
0551  15 11   D11
0552  07 02   RE2
0553  06 14   ST14
0554  07 03   RE3
0555  04 14   ×14
0556  06 01   ST1
0557  00 02   E2
0558  02 02   +2
0559  07 04   RE4
0560  06 14   ST14
0561  07 02   RE2
0562  03 14   −14
0563  08 04   *   Jo
0564  08 00   *   S
0565  00 03   E3
0566  09 02   *   α
0567  05 11   ÷11
0568  02 02   +2
0569  09 03   *   SP
0570  09 00   *   M
0571  10 10   f10
0572  07 00   RE0
0573  06 06   ST6
0574  07 01   RE1
0575  06 07   ST7
0576  00 00   E0
0577  06 00   ST0
0578  00 01   E1
0579  00 02   E2
0580  00 12   E12
0581  06 01   ST1
0582  09 02   *   α
0583  05 03   ÷3
0584  02 02   +2
0585  07 06   RE6
0586  06 00   ST0
0587  07 07   RE7
0588  06 01   ST1
0589  09 15   *   RT
```

```
0590  09 00   *  M
0591  10 03   f 3
0592  09 02   *  α
0593  05 11   ÷11
0594  02 02   +2
0595  00 09   E9
0596  00 09   E9
0597  00 09   E9
0598  06 00   ST0
0599  06 01   ST1
0600  09 02   *  α
0601  05 03   ÷3
0602  02 02   +2
0603  00 00   E0
0604  06 00   ST0
0605  00 01   E1
0606  06 01   ST1
0607  09 02   *  α
0608  05 08   ÷8
0609  02 02   +2
0610  00 00   E0
0611  06 00   ST0
0612  00 01   E1
0613  00 02   E2
0614  06 01   ST1
0615  09 02   *  α
0616  05 10   ÷10
0617  02 02   +2
0618  00 00   E0
0619  06 00   ST0
0620  00 04   E4
0621  00 00   E0
0622  06 01   ST1
0623  09 02   *  α
0624  05 03   ÷3
0625  02 02   +2
0626  00 03   E3
0627  00 02   E2
0628  06 02   ST2
0629  09 00   *  M
0630  08 07   *  Ω
0631  15 11   D11
0632  07 02   RE2
0633  15 02   D2
0634  01 01   T1
0635  00 03   E3
0636  02 02   +2
0637  00 02   E2
0638  00 00   E0
0639  00 12   E12
0640  06 00   ST0
0641  00 01   E1
0642  00 09   E9
0643  00 02   E2
0644  00 12   E12
0645  06 01   ST1
0646  09 02   *  α
0647  05 03   ÷3
0648  02 02   +2
0649  07 02   RE2
0650  06 00   ST0
0651  07 04   RE4
0652  09 02   *  α
0653  08 05   *  J
0654  08 00   *  S
0655  08 07   *  Ω
0656  07 04   RE4
0657  06 02   ST2
0658  09 02   *  α
0659  05 11   ÷11
0660  02 02   +2
0661  09 15   *  N
```

0662	09	00	* M
0663	10	04	f4
0664	09	02	* α
0665	05	11	÷11
0666	02	02	+2
0667	00	05	E5
0668	00	01	E1
0669	00	00	E0
0670	06	00	ST0
0671	00	09	E9
0672	00	09	E9
0673	00	09	E9
0674	06	01	ST1
0675	09	02	* α
0676	05	03	÷3
0677	02	02	+2
0678	00	00	E0
0679	06	00	ST0
0680	00	04	E4
0681	00	00	E0
0682	06	01	ST1
0683	09	02	* α
0684	05	03	÷3
0685	02	02	+2
0686	00	00	E0
0687	06	00	ST0
0688	00	01	E1
0689	06	01	ST1
0690	09	02	* α
0691	05	08	÷8
0692	02	02	+2
0693	00	00	E0
0694	06	00	ST0
0695	00	01	E1
0696	00	02	E2
0697	06	01	ST1
0698	09	02	* α
0699	05	10	÷10
0700	02	02	+2
0701	00	03	E3

0702	00	00	E0
0703	06	02	ST2
0704	09	00	* M
0705	09	07	* C'
0706	15	11	D11
0707	07	02	RE2
0708	06	05	ST5
0709	00	01	E1
0710	02	02	+2
0711	15	11	D11
0712	07	02	RE2
0713	06	06	ST6
0714	07	05	RE5
0715	08	12	* x^2
0716	06	14	ST14
0717	07	06	RE6
0718	08	12	* x^2
0719	02	14	+14
0720	08	13	* $\sqrt{x}$
0721	06	10	ST10
0722	07	05	RE5
0723	06	15	ST15
0724	08	01	* RE
0725	01	04	T4
0726	06	14	ST14
0727	00	02	E2
0728	00	00	E0
0729	05	14	÷14
0730	09	11	* D'
0731	09	01	* ST
0732	01	05	T5
0733	08	01	* RE
0734	01	05	T5
0735	04	15	×15
0736	08	12	* x^2
0737	06	14	ST14
0738	07	06	RE6
0739	06	15	ST15
0740	08	01	* RE
0741	01	05	T5

0742	04	15	×15
0743	08	12	* x^2
0744	02	14	+14
0745	08	13	* $\sqrt{x}$
0746	06	08	ST 8
0747	07	06	RCL 6
0748	08	05	* $1/x$
0749	08	00	* S
0750	09	06	* S'
0751	07	05	RCL 5
0752	06	14	ST 14
0753	08	05	* $1/x$
0754	08	00	* S
0755	08	08	* N
0756	07	10	RCL 10
0757	05	14	÷14
0758	09	06	* S'
0759	06	09	ST 9
0760	08	00	* S
0761	08	11	* e^x
0762	09	00	* M
0763	09	06	* S'
0764	07	05	RCL 5
0765	06	14	ST 14
0766	08	05	* $1/x$
0767	08	00	* S
0768	09	08	* T'
0769	00	01	E 1
0770	00	08	E 8
0771	00	00	E 0
0772	06	09	ST 9
0773	07	10	RCL 10
0774	05	14	÷14
0775	09	06	* S'
0776	03	09	−9
0777	08	00	* S
0778	08	11	* e^x
0779	09	00	* M
0780	08	08	* N
0781	00	12	E 12
0782	06	14	ST 14
0783	00	03	E 3
0784	00	06	E 6
0785	00	00	E 0
0786	06	09	ST 9
0787	07	10	RCL 10
0788	05	14	÷14
0789	09	06	* S'
0790	03	09	−9
0791	08	00	* S
0792	08	11	* e^x
0793	09	00	* M
0794	09	08	* T'
0795	00	12	E 12
0796	06	14	ST 14
0797	00	01	E 1
0798	00	08	E 8
0799	00	00	E 0
0800	06	09	ST 9
0801	07	10	RCL 10
0802	05	14	÷14
0803	09	06	* S'
0804	02	09	+9
0805	08	00	* S
0806	08	11	* e^x
0807	09	00	* M
0808	08	11	* e^x
0809	07	08	RCL 8
0810	15	02	D 2
0811	03	03	−3
0812	00	00	E 0
0813	06	00	ST 0
0814	00	01	E 1
0815	00	02	E 2
0816	06	01	ST 1
0817	09	02	* α
0818	05	03	÷3
0819	02	02	+2
0820	07	09	RCL 9
0821	15	02	D 2

```
0822   03 03    -3
0823   00 02    E 2
0824   00 00    E 0
0825   00 12    E 12
0826   06 00    ST 0
0827   00 02    E 2
0828   00 00    E 0
0829   00 04    E 4
0830   00 12    E 12
0831   06 01    ST 1
0832   09 02    *    α
0833   05 03    ÷3
0834   02 02    +2
0835   00 02    E 2
0836   02 02    +2
0837   07 04    RE 4
0838   06 14    ST 14
0839   07 02    RE 2
0840   03 14    -14
0841   08 04    *  J0
0842   08 00    *  S
0843   09 07    *    C'
0844   07 04    RE 4
0845   06 02    ST 2
0846   09 02    *    α
0847   05 11    ÷11
0848   02 02    +2
0849   09 15    *    RT
0850   09 14    *    EP
```

APPENDIX H
SCHOTTKY BARRIER CAPACITANCE-PLOTTING AND LISTING PROGRAM

Verify = 7706

```
0000  09 00   *  M          0040  02 02   +2
0001  10 05   f5            0041  00 01   E1
0002  09 02   *  α          0042  03 02   -2
0003  05 11   ÷11           0043  09 04   *  J
0004  02 02   +2            0044  08 00   *  S
0005  00 09   E9            0045  09 13   *  ∫
0006  00 08   E8            0046  00 00   E0
0007  06 00   ST0           0047  06 00   ST0
0008  00 01   E1            0048  00 09   E9
0009  00 00   E0            0049  00 00   E0
0010  00 01   E1            0050  06 01   ST1
0011  06 01   ST1           0051  09 02   *  α
0012  09 02   *  α          0052  05 02   ÷2
0013  05 03   ÷3            0053  02 02   +2
0014  02 02   +2            0054  08 00   *  S
0015  00 01   E1            0055  08 13   *  √x
0016  00 03   E3            0056  09 00   *  M
0017  06 02   ST2           0057  09 13   *  ∫
0018  09 00   *  M          0058  00 00   E0
0019  08 13   *  √x         0059  06 00   ST0
0020  00 01   E1            0060  00 01   E1
0021  00 00   E0            0061  00 08   E8
0022  06 00   ST0           0062  00 00   E0
0023  00 00   E0            0063  00 12   E12
0024  06 01   ST1           0064  06 01   ST1
0025  09 02   *  α          0065  09 02   *  α
0026  05 02   ÷2            0066  05 02   ÷2
0027  02 02   +2            0067  02 02   +2
0028  00 02   E2            0068  00 01   E1
0029  00 00   E0            0069  00 01   E1
0030  00 12   E12           0070  06 02   ST2
0031  06 00   ST0           0071  09 00   *  M
0032  09 02   *  α          0072  09 11   *  ∫'
0033  05 02   ÷2            0073  00 00   E0
0034  02 02   +2            0074  06 00   ST0
0035  00 01   E1            0075  00 01   E1
0036  00 00   E0            0076  00 00   E0
0037  06 00   ST0           0077  06 01   ST1
0038  09 02   *  α          0078  09 02   *  α
0039  05 02   ÷2            0079  05 02   ÷2
```

```
0080  02 02   +2
0081  00 02   E2
0082  00 00   E0
0083  00 12   E12
0084  06 01   ST1
0085  09 02   *   α
0086  05 02   ÷2
0087  02 02   +2
0088  00 01   E1
0089  00 00   E0
0090  06 01   ST1
0091  09 02   *   α
0092  05 02   ÷2
0093  02 02   +2
0094  00 01   E1
0095  03 02   -2
0096  09 04   *   J
0097  08 00   *  S
0098  11 06   F6
0099  00 09   E9
0100  00 00   E0
0101  06 00   ST0
0102  00 00   E0
0103  06 01   ST1
0104  09 02   *   α
0105  05 02   ÷2
0106  02 02   +2
0107  08 00   *  S
0108  09 11   *   ₩
0109  09 00   *   M
0110  11 06   F6
0111  00 03   E3
0112  00 07   E7
0113  00 00   E0
0114  00 12   E12
0115  06 00   ST0
0116  00 02   E2
0117  00 00   E0
0118  00 00   E0
0119  06 01   ST1
0120  09 02   *   α
0121  05 03   ÷3
0122  02 02   +2
0123  00 01   E1
0124  06 01   ST1
0125  09 02   *   α
0126  05 08   ÷8
0127  02 02   +2
0128  00 01   E1
0129  00 05   E5
0130  00 12   E12
0131  06 00   ST0
0132  00 00   E0
0133  06 01   ST1
0134  09 02   *   α
0135  05 10   ÷10
0136  02 12   +12
0137  01 12   T12
0138  00 05   E5
0139  01 12   T12
0140  02 12   +12
0141  01 04   T4
0142  02 07   +7
0143  01 12   T12
0144  02 06   +6
0145  02 12   +12
0146  02 05   +5
0147  02 02   +2
0148  00 04   E4
0149  00 00   E0
0150  00 00   E0
0151  00 12   E12
0152  06 00   ST0
0153  00 06   E6
0154  00 09   E9
0155  00 00   E0
0156  00 12   E12
0157  06 01   ST1
0158  09 02   *   α
0159  05 03   ÷3
```

```
0160   02 02     +2
0161   00 00     E0
0162   06 00     SF0
0163   00 01     E1
0164   00 02     E2
0165   06 01     SF1
0166   09 02     *     a
0167   05 10     ÷10
0168   05 03     ÷3
0169   01 14     T14
0170   01 09     T9
0171   03 15     -15
0172   02 07     +7
0173   01 12     T12
0174   00 15     E15
0175   02 05     +5
0176   05 11     ÷11
0177   02 02     +2
0178   09 03     *     SP
```

0179	09	00	* M
0180	10	06	f 6
0181	07	04	RCL 4
0182	06	03	ST 3
0183	00	03	E 3
0184	00	00	E 0
0185	06	02	ST 2
0186	00	01	E 1
0187	06	05	ST 5
0188	09	03	* SP
0189	09	00	* M
0190	08	15	* 1/x
0191	15	11	D 11
0192	06	03	ST 3
0193	00	01	E 1
0194	02	03	+ 3
0195	15	11	D 11
0196	07	02	RCL 2
0197	06	06	ST 6
0198	00	01	E 1
0199	02	02	+ 2
0200	15	11	D 11
0201	07	02	RCL 2
0202	06	07	ST 7
0203	00	01	E 1
0204	02	02	+ 2
0205	15	11	D 11
0206	07	02	RCL 2
0207	06	08	ST 8
0208	00	01	E 1
0209	02	02	+ 2
0210	07	06	RCL 6
0211	08	12	* x^2
0212	06	14	ST 14
0213	00	01	E 1
0214	06	15	ST 15
0215	07	07	RCL 7
0216	03	15	− 15
0217	08	12	* x^2
0218	02	14	+ 14
0219	07	06	RCL 6
0220	06	15	ST 15
0221	00	02	E 2
0222	04	15	× 15
0223	07	14	RCL 14
0224	05	15	÷ 15
0225	00	12	E 12
0226	08	15	* 1/x
0227	06	14	ST 14
0228	00	01	E 1
0229	00	00	E 0
0230	00	00	E 0
0231	05	14	÷ 14
0232	09	02	* α
0233	10	00	f 0
0234	05	14	÷ 14
0235	07	08	RCL 8
0236	05	14	÷ 14
0237	15	11	D 11
0238	06	03	ST 3
0239	00	01	E 1
0240	02	03	+ 3
0241	00	01	E 1
0242	02	05	+ 5
0243	09	03	* SP
0244	08	00	* S
0245	08	15	* 1/x
0246	09	15	* RT

0247	09	00	* M	0287	07	15	RE15
0248	10	07	f7	0288	06	09	ST9
0249	09	02	* α	0289	15	02	D2
0250	05	11	÷11	0290	02	02	+2
0251	02	02	+2	0291	00	10	E10
0252	00	08	E8	0292	00	08	E8
0253	00	01	E1	0293	06	06	ST6
0254	06	00	ST0	0294	00	05	E5
0255	00	06	E6	0295	06	02	ST2
0256	00	03	E3	0296	09	00	* M
0257	06	01	ST1	0297	11	10	F10
0258	09	02	* α	0298	07	15	RE15
0259	05	03	÷3	0299	06	14	ST14
0260	02	02	+2	0300	07	06	RE6
0261	00	01	E1	0301	04	14	×14
0262	06	01	ST1	0302	00	10	E10
0263	09	02	* α	0303	00	02	E2
0264	05	08	÷8	0304	03	06	-6
0265	02	02	+2	0305	00	01	E1
0266	00	00	E0	0306	03	02	-2
0267	06	00	ST0	0307	09	04	* J.
0268	00	01	E1	0308	08	00	* S
0269	00	02	E2	0309	11	11	F11
0270	06	01	ST1	0310	00	00	E0
0271	09	02	* α	0311	06	00	ST0
0272	05	10	÷10	0312	00	01	E1
0273	02	02	+2	0313	00	00	E0
0274	07	04	RE4	0314	00	08	E8
0275	06	02	ST2	0315	06	01	ST1
0276	15	11	D11	0316	09	02	* α
0277	07	02	RE2	0317	05	03	÷3
0278	06	07	ST7	0318	02	02	+2
0279	09	13	* IXI	0319	07	14	RE14
0280	06	06	ST6	0320	15	02	D2
0281	00	02	E2	0321	02	02	+2
0282	02	02	+2	0322	08	00	* S
0283	08	00	* S	0323	11	10	F10
0284	11	12	F12	0324	09	00	* M
0285	09	00	* M	0325	11	11	F11
0286	11	04	F4	0326	00	01	E1

```
0327  00 03   E 3
0328  00 00   E 0
0329  06 01   ST 1
0330  09 02   *    α
0331  05 03   ÷ 3
0332  03 01   - 1
0333  01 06   T 6
0334  03 01   - 1
0335  03 01   - 1
0336  02 02   + 2
0337  00 01   E 1
0338  00 01   E 1
0339  00 00   E 0
0340  06 01   ST 1
0341  09 02   *    α
0342  05 03   ÷ 3
0343  02 02   + 2
0344  07 15   RE 15
0345  06 14   ST 14
0346  00 10   E 10
0347  00 02   E 2
0348  04 14   × 14
0349  00 12   E 12
0350  15 02   D 2
0351  02 02   + 2
0352  07 04   RE 4
0353  06 02   ST 2
0354  00 01   E 1
0355  02 02   + 2
0356  15 11   D 11
0357  07 02   RE 2
0358  06 06   ST 6
0359  06 07   ST 7
0360  00 02   E 2
0361  02 02   + 2
0362  09 00   *    M
0363  11 12   F 12
0364  15 11   D 11
0365  07 02   RE 2
0366  09 13   *    IXI
0367  03 06   - 6
0368  08 05   *    J+
0369  08 00   *    S
0370  11 13   F 13
0371  07 07   RE 7
0372  09 13   *    IXI
0373  06 06   ST 6
0374  00 02   E 2
0375  02 02   + 2
0376  07 03   RE 3
0377  06 14   ST 14
0378  07 02   RE 2
0379  03 14   - 14
0380  00 01   E 1
0381  03 14   - 14
0382  08 05   *    J+
0383  08 00   *    S
0384  11 14   F 14
0385  08 00   *    S
0386  11 12   F 12
0387  09 00   *    M
0388  11 13   F 13
0389  15 11   D 11
0390  07 02   RE 2
0391  06 07   ST 7
0392  09 13   *    IXI
0393  06 06   ST 6
0394  00 02   E 2
0395  02 02   + 2
0396  07 03   RE 3
0397  06 14   ST 14
0398  07 02   RE 2
0399  03 14   - 14
0400  00 01   E 1
0401  03 14   - 14
0402  08 05   *    J+
0403  08 00   *    S
0404  11 14   F 14
0405  08 00   *    S
0406  11 12   F 12
```

```
0407  09 00   *  M
0408  11 14   F14
0409  07 07   RE7
0410  06 15   ST15
0411  00 01   E 1
0412  02 14   +14
0413  09 04   *  J0
0414  08 00   *  S
0415  11 04   F 4
0416  09 00   *  M
0417  11 15   F15
0418  07 15   RE15
0419  09 12   *  I
0420  08 04   *  J0
0421  08 00   *  S
0422  11 00   F 0
0423  00 01   E 1
0424  00 00   E 0
0425  04 15   ×15
0426  08 00   *  S
0427  11 15   F15
0428  09 00   *  M
0429  11 00   F 0
0430  06 14   ST14
0431  07 15   RE15
0432  03 14   -14
0433  00 01   E 1
0434  02 14   +14
0435  02 15   +15
0436  06 14   ST14
0437  00 10   E10
0438  00 08   E 8
0439  06 02   ST 2
0440  00 09   E 9
0441  00 01   E 1
0442  00 08   E 8
0443  06 00   ST 0
0444  00 02   E 2
0445  00 00   E 0
0446  00 00   E 0
0447  00 12   E12
0448  06 01   ST 1
0449  09 02   *  A
0450  05 03   ÷3
0451  02 02   +2
0452  00 02   E 2
0453  03 14   -14
0454  08 04   *  J0
0455  08 00   *  S
0456  11 01   F 1
0457  09 00   *  M
0458  11 02   F 2
0459  00 02   E 2
0460  00 10   E10
0461  00 05   E 5
0462  06 14   ST14
0463  06 15   ST15
0464  06 08   ST 8
0465  15 02   D 2
0466  01 01   T 1
0467  08 00   *  S
0468  11 03   F 3
0469  09 00   *  M
0470  11 01   F 1
0471  00 05   E 5
0472  06 14   ST14
0473  06 15   ST15
0474  06 08   ST 8
0475  15 02   D 2
0476  01 01   T 1
0477  09 00   *  M
0478  11 03   F 3
0479  00 01   E 1
0480  00 08   E 8
0481  00 00   E 0
0482  00 12   E12
0483  06 00   ST 0
0484  00 04   E 4
0485  00 08   E 8
0486  00 12   E12
```

```
0487   06 01    SI 1
0488   09 02    *   α
0489   05 03    ÷3
0490   02 02    +2
0491   07 15    RE15
0492   06 14    SI14
0493   07 02    RE2
0494   04 14    ×14
0495   15 02    D2
0496   01 01    T 1
0497   00 10    E10
0498   00 02    E 2
0499   03 02    −2
0500   09 04    *   J
0501   08 00    *  S
0502   11 07    F 7
0503   08 00    *  S
0504   11 03    F 3
0505   09 00    *   M
0506   11 07    F 7
0507   09 02    *   α
0508   05 11    ÷11
0509   02 02    +2
0510   09 03    *   SP
```

```
0511  09 00   *  M
0512  10 08   f8
0513  00 01   E1
0514  00 00   E0
0515  00 01   E1
0516  06 00   ST0
0517  00 09   E9
0518  00 09   E9
0519  00 09   E9
0520  06 01   ST1
0521  09 02   *  α
0522  05 03   ÷3
0523  02 02   +2
0524  00 01   E1
0525  06 01   ST1
0526  09 02   *  α
0527  05 08   ÷8
0528  02 02   +2
0529  00 00   E0
0530  06 00   ST0
0531  00 01   E1
0532  00 02   E2
0533  06 01   ST1
0534  09 02   *  α
0535  05 10   ÷10
0536  02 02   +2
0537  07 04   RE4
0538  06 02   ST2
0539  00 08   E8
0540  00 09   E9
0541  00 08   E8
0542  06 10   ST10
0543  05 08   ÷8
0544  08 15   *  ½
0545  06 08   ST8
0546  00 01   E1
0547  00 11   E11
0548  00 01   E1
0549  00 02   E2
0550  04 08   ×8
0551  07 10   RE10
0552  05 09   ÷9
0553  08 15   *  ½
0554  09 13   *  IXI
0555  06 09   ST9
0556  00 00   E0
0557  06 00   ST0
0558  06 01   ST1
0559  06 10   ST10
0560  06 11   ST11
0561  15 11   D11
0562  07 02   RE2
0563  06 01   ST1
0564  07 09   RE9
0565  04 01   ×1
0566  00 01   E1
0567  02 02   +2
0568  15 11   D11
0569  07 02   RE2
0570  06 00   ST0
0571  07 08   RE8
0572  04 00   ×0
0573  00 01   E1
0574  02 02   +2
0575  09 02   *  α
0576  05 03   ÷3
0577  01 06   T6
0578  02 02   +2
0579  11 09   F9
0580  07 03   RE3
0581  06 14   ST14
0582  07 02   RE2
0583  03 14   -14
0584  08 04   *  Jo
0585  08 00   *  S
0586  11 08   F8
0587  09 02   *  α
0588  05 11   ÷11
0589  02 02   +2
0590  09 03   *  SP
```

```
0591  09 00   *    M
0592  11 08   F 8
0593  07 10   RE10
0594  02 00   +0
0595  07 11   RE11
0596  02 01   +1
0597  07 00   RE0
0598  00 12   E12
0599  06 00   ST0
0600  07 01   RE1
0601  00 12   E12
0602  06 01   ST1
0603  15 11   D11
0604  07 02   RE2
0605  06 14   ST14
0606  07 09   RE9
0607  04 14   ×14
0608  02 01   +1
0609  00 01   E1
0610  02 02   +2
0611  15 11   D11
0612  07 02   RE2
0613  06 14   ST14
0614  07 08   RE8
0615  04 14   ×14
0616  02 00   +0
0617  00 01   E1
0618  03 02   −2
0619  09 02   *    α
0620  05 03   ÷3
0621  01 06   T6
0622  02 02   +2
0623  11 09   F9
0624  07 00   RE0
0625  06 14   ST14
0626  09 12   *    I
0627  03 14   −14
0628  06 10   ST10
0629  07 01   RE1
0630  06 14   ST14
0631  09 12   *    I
0632  03 14   −14
0633  06 11   ST11
0634  15 11   D11
0635  07 02   RE2
0636  06 14   ST14
0637  07 09   RE9
0638  04 14   ×14
0639  06 01   ST1
0640  00 01   E1
0641  02 02   +2
0642  15 11   D11
0643  07 02   RE2
0644  06 14   ST14
0645  07 08   RE8
0646  04 14   ×14
0647  06 00   ST0
0648  00 01   E1
0649  02 02   +2
0650  07 03   RE3
0651  06 14   ST14
0652  07 02   RE2
0653  03 14   −14
0654  08 04   *    J0
0655  08 00   *    S
0656  11 08   F8
0657  09 02   *    α
0658  05 11   ÷11
0659  02 02   +2
0660  09 03   *    SP
0661  09 00   *    M
0662  11 09   F9
0663  07 00   RE0
0664  06 06   ST6
0665  07 01   RE1
0666  06 07   ST7
0667  00 00   E0
0668  06 00   ST0
0669  00 01   E1
0670  00 02   E2
```

```
0671   00 12     EIz
0672   06 01     ST 1
0673   09 02     *     α
0674   05 03     ÷3
0675   02 02     +2
0676   07 06     RE 6
0677   06 00     ST 0
0678   07 07     RE 7
0679   06 01     ST 1
0680   09 15     *     RT
0681   09 03     *     SP
```

```
0682  09 00   *    M
0683  10 09   f9
0684  09 02   *    α
0685  05 11   ÷11
0686  02 02   +2
0687  00 09   E9
0688  00 09   E9
0689  00 09   E9
0690  06 00   ST0
0691  00 01   E1
0692  00 00   E0
0693  00 01   E1
0694  06 01   ST1
0695  09 02   *    α
0696  05 03   ÷3
0697  02 02   +2
0698  00 00   E0
0699  06 00   ST0
0700  00 01   E1
0701  06 01   ST1
0702  09 02   *    α
0703  05 08   ÷8
0704  02 02   +2
0705  00 01   E1
0706  00 02   E2
0707  06 01   ST1
0708  09 02   *    α
0709  05 10   ÷10
0710  01 14   T14
0711  01 09   T9
0712  03 15   −15
0713  02 07   +7
0714  01 01   T1
0715  05 03   ÷3
0716  05 03   ÷3
0717  05 03   ÷3
0718  05 03   ÷3
0719  05 03   ÷3
0720  00 05   E5
0721  01 04   T4
0722  02 12   +12
0723  01 09   T9
0724  00 14   E14
0725  01 12   T12
0726  01 13   T13
0727  01 12   T12
0728  02 13   +13
0729  01 01   T1
0730  02 02   +2
0731  00 02   E2
0732  00 00   E0
0733  00 12   E12
0734  06 00   ST0
0735  00 02   E2
0736  00 04   E4
0737  00 00   E0
0738  00 12   E12
0739  06 01   ST1
0740  09 02   *    α
0741  05 03   ÷3
0742  02 02   +2
0743  07 04   RE4
0744  06 02   ST2
0745  09 00   *    M
0746  10 15   f15
0747  15 11   D11
0748  07 02   RE2
0749  15 02   D2
0750  02 02   +2
0751  00 00   E0
0752  06 00   ST0
0753  00 03   E3
0754  00 00   E0
0755  06 01   ST1
0756  09 02   *    α
0757  05 03   ÷3
0758  02 02   +2
0759  00 01   E1
0760  02 02   +2
0761  15 11   D11
```

```
0762   07  02     RE 2
0763   06  14     ST14
0764   00  01     E 1
0765   00  11     E11
0766   00  01     E 1
0767   00  02     E 2
0768   04  14     ×14
0769   15  02     D 2
0770   01  02     T 2
0771   00  02     E 2
0772   00  00     E 0
0773   00  12     E12
0774   06  00     ST 0
0775   00  01     E 1
0776   00  06     E 6
0777   00  02     E 2
0778   00  12     E12
0779   06  01     ST 1
0780   09  02     *    α
0781   05  03     ÷3
0782   02  02     +2
0783   00  01     E 1
0784   02  02     +2
0785   06  14     ST14
0786   07  03     RE 3
0787   03  14     -14
0788   08  04     *  Jo
0789   08  00     *  S
0790   10  15     f15
0791   09  02     *    α
0792   05  11     ÷11
0793   02  02     +2
0794   09  03     *    SP
0795   09  14     *    EP
```

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